QH
C17

JOURNAL
OF THE
FISHERIES RESEARCH BOARD
OF CANADA

Volume 26, No. 12

CONTENTS

	Pages
MacCrimmon, Hugh R., and T. L. Marshall. World distribution of brown trout, *Salmo trutta*	2337–2348
Ingram, W. M., and B. J. Simmons III. Intermandibularis and stomach in relation to other muscle components of an elasmobranch (*Raja radiata*)	2349–2360
Pfeiler, Edwin E., and Robert L. Bidwell, Jr. Fish otoliths in cetacean stomachs and their importance in interpreting feeding habits	2361–2374
Kalle, K. Some physical and chemical characteristics of Arctic fresh waters in Alaska and northwestern Canada	2375–2387
Semakula, S. N., and P. A. Larkin. Age, growth, food, and yield of the white sturgeon (*Acipenser transmontanus*) of the Fraser River, British Columbia	2389–2402
Hart, J. L. Respiration of the Winnipeg goldeye (*Hiodon alosoides*)	2403–2418
Hubbard, Edward M. Stratification and mixing in coastal waters of the western Gulf of Maine during summer	2419–2431
Mounib, M. S., F. C. Hwang, and D. R. Idler. Cryogenic preservation of Atlantic salmon (*Salmo salar*) sperm	2433–2437
Crossman, E. J. Differences between North American and European populations of the rainbow trout revealed by transplantation	2439–2451
McDonald, J. A., and A. H. Bauer. Experimental plantings of brook trout (*Salvelinus fontinalis*) from furunculosis-infected stock	2453–2459
Wilkinson, P. F. Multiple haemoglobins of the Atlantic salmon (*Salmo salar*)	2461–2465
Day, Douglas S., and William G. Pearcy. Species associations of benthic fishes on the continental shelf and slope of Oregon	2467–2475
Anderson, John M. Effects of industrial DDT on the lateral line of brook trout, *Salvelinus fontinalis*	2477–2483
Scarratt, D. J. An artificial reef for lobsters (*Homarus americanus*)	2485–2490

NOTES

Metabolism of the radioisotope ^{65}Zn in the freshwater mussel *Anodonta californiensis*. By Gunnar I. Fagerlund and Roy E. Nakatani	2491–2494
Effects of chilled storage on viability of stored ova and sperm of sockeye and pink salmon. By F. C. Withler and R. B. Morley	2495–2499
Simplification of a method of computing recruitment rates. By K. Radway Allen	2501–2503
Reproductive isolating mechanisms of the Blackspotted stickleback, *Gasterosteus wheatlandi*. By Howard E. Bigelow	2503–2508
New records of the hermit crab *Eupagurus pubescens* in the northwest Atlantic. By Fenwick Lamb	2507–2510
Localization of enzyme bands in the starch-gel and moving-boundary electrophoretograms of fish muscle. By C. Gosselin-Roy, G. Hamon, and R. R. Brown	2511–2514
Polymorphism in carp muscle creatine kinase. By R. K. Scopes and C. Gosselin	2515–2519
Variation in environmentally induced levels of salinity in the euryhaline cyprinodontid *Fundulus heteroclitus* and *F. diaphanus* after domestic acclimation. By E. T. Garside and C. M. Jonassen	2521–2530
Late occurrence of Hyperiid hosts (Rhabdosoma hippocrepidis) in the Bay of Fundy. By E. E. Bleakney	2531–2532
Lobsters (*Homarus*) 528 fath deep off St. John's, Newfoundland. By H. J. Squires and A. G. Dawe	2533–2534
Overwintering of American lobsters, *Homarus americanus*, in burrows in Malpeque Bay, Prince Edward Island. By M. L. H. Dickie	2535–2537
Occurrence of the seaboorn sculpin (Cyottopsis rastrosus) in Newfoundland waters. By A. Hurley	2539–2541
First record of the sculpin *Myoxocephalus thompsonii* and other rare fishes from the Ottawa River, southeastern Ontario. By Charles Douglas and W. Van Vliet	2543–2547
Spatial distribution and allelic distributions in the copepodites of *Neocalanus* in the Gulf of Alaska and Puget Sound. By Stephen W. Hagen, Jacqueline E. Purple, and David S. Bell	2549–2551
Relationship between weight from length measures. By A. V. Tyurin and W. E. Ricker	2553–2557
Parasites of the lumpfish and herring as indicators of Atlantic cod migrations in the Gulf of St. Lawrence, the Straits of Belle Isle, and the Labrador Sea. By Wilfred Wilson	2559–2563
Index to publications for 1969	2565–2569

OTTAWA
DECEMBER
1969

JOURNAL OF THE FISHERIES RESEARCH BOARD OF CANADA

Submissions for publication in the *Journal of the Fisheries Research Board of Canada* should concern aquatic organisms or environments that are relevant to Canada. They may be either original research articles or reviews, in English or in French. Articles are accepted without limitations as to origin, but must not have been published elsewhere or copyrighted. Opinions expressed by authors do not necessarily reflect those of the Board or policies of the Ministry of Fisheries of Canada.

A guide to contributors is included at the back of each *Journal* issue.

The publication of the *Journals*, together with its predecessors, has been continuous since 1901. Its predecessors are *Contributions to Canadian Biology* published from 1901 to 1925, *Contributions to Canadian Biology and Fisheries* from 1926 to 1934, and the *Journal of the Biological Board of Canada* from 1934 to 1937.

This *Journal* is published in annual volumes of twelve issues. This issue (Vol. 25, No. 12) was published December 31, 1968.

Editor:

J. C. STEVENSON, PH.D.

Associate Editor: L. W. BILLINGSLEY, PH.D.
Assistant Editor: R. H. WIGMORE, M.SC.

Production: R. L. MacIntyre, Marilyn Campbell, B.A.

Scientific Documentation: Martha Skulski, PH.D.

Fisheries Research Board of Canada
Office of the Editor
116 Lisgar Street
Ottawa 4, Ont., Canada

Manuscripts for publication should be addressed to the Editor

---

All Fisheries Research Board of Canada publications are for sale by the Queen's Printer, Ottawa. Remittances must be in advance, payable in Canadian funds to the order of the Receiver General of Canada. Subscription rates to the *Journal* are: Canada, United States, Mexico, $6.50, single issue $1.00; to other countries, $7.15 and $1.25.

The Fisheries Research Board of Canada also publishes a *Bulletin* series (irregularly), an *Annual Report*, and a biennial Review of investigations. All publications may be consulted at Board establishments located at Ottawa; Nanaimo and Vancouver, B.C.; Winnipeg, Man.; Ste. Anne de Bellevue and Grande-Rivière, Que.; St. Andrews, N.B.; Halifax and Dartmouth, N.S.; Elderdie, P.E.I.; and St. John's, Nfld.

World Distribution of Brown Trout, *Salmo trutta*[1]

By Hugh R. MacCrimmon and T. L. Marshall

Department of Zoology
University of Guelph, Guelph, Ont.

ABSTRACT

During the past century the Eurasian and North African range of the brown trout, *Salmo trutta* L., has been extended to include discontinuous populations on all continents except Antarctica. Primary factors affecting the establishment of naturalized populations are water temperature, precipitation, and suitable spawning grounds. Any future major expansion in the world distribution of the brown trout, with the possible exception of Asia, is unlikely.

INTRODUCTION

During the past century the pristine range of the brown trout, *Salmo trutta* Linnaeus, in Eurasia and North Africa, has been extended through introduction to include waters on all continents except Antarctica.

Linnaeus, when naming the trout of Sweden *Salmo trutta* in 1758, regarded the sea trout (*S. eriox*) and the brook trout (*S. fario*) as distinct species. The latter species must not be confused with the North American brook trout, *Salvelinus fontinalis* (American Fisheries Society, 1960). After that time various local representatives of the genus were given a variety of common and specific names (Regan, 1911) which included the common trout (*S. fario, ausonii, gairnardi, cornubiensis*), the English salmon trout (*S. trutta, eriox, cambricus, albus, phinoc, brachypoms*), the golden estuarian trout (*S. estuarius, orcadensis, gallivensis*), the great black lake trout (*S. ferox, nigripinnis*), the gillaroo (*S. stomachicus*), and the silver or Loch Leven trout (*S. caecifer, levenensis*). The exchange of brown trout stocks among European countries, such as the transfer of German brown trout to England in 1884 (Smiley, 1884) and to Italy in 1885 (Pavesi, 1887), further complicated the problem of speciation.

Modern ichthyologists, however, generally accept the concept of Günther (1866), Regan (1911), Jordan (1926), and Hubbs (1930) that there is but one species, *Salmo trutta*, and that trout with distinctive features should be recognized at only the subspecific level, if at all.

Most populations of brown trout now resident in hatcheries and natural waters throughout the world stem from the following three sources: sea run specimens of the European trout (*Salmo trutta trutta*), European trout permanently resident in fresh water (*Salmo trutta fario*), and the trout (*Salmo rutta levenensis*) from Loch Leven, and other waters of Scotland and northern

[1]Received for publication May 29, 1968.

J. Fish. Res. Bd. Canada, **25**(12): 2527–2548, 1968.
Printed in Canada.

England. Because of interbreeding in fish culture programmes, and the introduction of hybrids or several stocks to many waters, it would seem imprudent for practical purposes to identify the brown trout beyond the specific level (Wiggins, MS, 1950).

The objectives of this paper are: firstly, to present an account of known attempts to introduce the brown trout (*Salmo trutta* L.) beyond its native range; and secondly, to document the present world distribution of the species which has resulted from these introductions.

NATIVE RANGE

The native range of the brown trout (Fig. 1) has been established essentially from published material by Seeley (1886), Bean (1888), Dahl (1918, 1919), Berg (1932), Tchernavin (1939), Wiggins (MS, 1950), Nikolskii (1937, 1961), and Vladykov (1931, 1963).

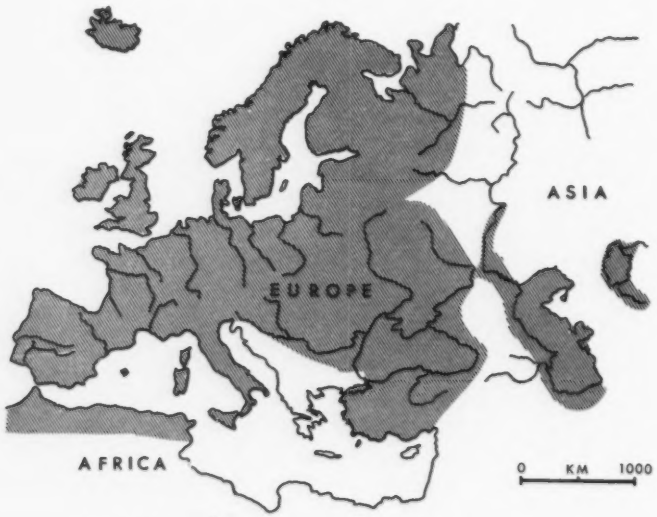


FIG. 1. Native distribution of *Salmo trutta*.

The early distribution of the species is believed to have extended from Iceland and the northern coasts of Europe southward to the countries fronting on the Mediterranean Sea, the islands of Corsica and Sardinia, and Algeria in northern Africa. The range extended eastward from the Atlantic drainage towards the northern slopes of the Himalayas. Migratory brown trout inhabited the Black, Caspian, and Aral seas and their tributaries.

KNOWN INTRODUCTIONS AUSTRALIA AND NEW ZELAND

AUSTRALIA

The earliest known introduction of the brown trout beyond its native range was a planting made in Tasmania in 1864 (Lake, personal communication).[2] The ova, obtained from the Wey and River Itchen at High Wycombe, left London, England, on January 21, 1864, and arrived in Tasmania 91 days later. Although only some 300 eggs hatched, a small planting made in the Plenty River would seem to have established a naturalized population there. Of a further experiment of 15,000 trout eggs transported to Tasmania in the following year, about 500 fry were hatched (Frost and Brown, 1967). From the progeny of these stocks came widespread introductions into the rivers of Tasmania, mainland Australia, and New Zealand. At present, naturalized populations of brown trout occur in most waters of Tasmania (Lynch, personal communication).

On mainland Australia, the possibility of a second importation from England to Victoria has been noted by Tonbridge (personal communication). Weatherley and Lake (1967) citing Roughley (1951), also indicate that eggs from Tasmanian stocks were distributed in Victoria. Progeny of the Victorian stocks were then introduced into the waters of New South Wales by 1888.

Presently, brown trout occur in tableland streams of the eastern highlands of New South Wales and Victoria above 600 m elevation (Fig. 2). In the case of steep mountain streams they may be found as low as 300 m (Lake, 1957).

FIG. 2. Naturalized distribution of *Salmo trutta* in Australia and New Zealand.

[2]All personnal communications cited in this paper are listed alphabetically after the References section of this paper.

Weatherley and Lake (1967) further note that in the more northern regions of the Highlands in New South Wales, waters below 1200 m provide only a marginal summer existence.

Attempts to introduce brown trout into Queensland began in 1896, when the Government purchased 32,000 ova from New Zealand. To date, the principal areas of introduction have been the Stanthorpe and Warwick districts in the south and the Atherton Tablelands of the north (Haysom, personal communication). The known extent of naturalized populations is limited to the former Districts.

Although no dates of introduction are given, trout (brown or rainbow) also may be found to a limited extent in the Pemberton region of Western Australia and in some small streams near Adelaide, South Australia (Weatherley and Lake, 1967).

New Zealand

In New Zealand, Hobbs (1948) reported that imports from Tasmania continued from at least 1867 to 1875 at which time populations on the South Island, through the effort of societies in Otago and Canterbury provinces, became self-supporting. By 1885, plantings on the North Island had become equally successful.

Little (personal communication) reports that brown trout have since been stocked in almost every conceivable lake, river, or stream, such that the present naturalized distribution encompasses every suitable ecological niche in the confines of New Zealand (Fig. 2). Little also mentions that supplemental private plantings by acclimatization societies have continued in support of the popular sport fishery.

Three thousand brown trout fry sent to the Chatham Islands (1100 km east of New Zealand) failed to survive a voyage there in 1916 or 1917. Further private introductions between 1934 and 1949 also were unsuccessful (Skrynski, 1967).

ASIA

India

European brown trout were first transplanted to the District of Nilgiris, State of Madras, in 1863. These, and later plantings of the Loch Leven variety between 1866 and 1873, failed to establish populations (Tripathi, personal communication; Wiggins, MS, 1950).

The most important introduction to India was made in 1889 (Table I) when brown trout ova of European origin were hatched in the more northerly State of Kashmir. Here they became firmly established in a number of streams of the Kashmir Valley (Fig. 3) and some 20 years later progeny of these fish were being distributed in the waters of two adjacent southern states, Himachal and Uttar Pradesh (Tripathi, personal communication). Himachal State met with good success in naturalizing the species although unprecedented floods in 1947 were reported to have destroyed river populations in the Chamba

TABLE I. Introductions of brown trout to India.

State/district	Year of introduction	Source	Present status
Madras			
Nilgiris	1863–73	England	Apparent failure
Jammu & Kashmir			
Kashmir	1889	Europe	Well established
Jammu	1963	Kashmir	Not yet known
Nefa	1966	"	Not yet known
Uttar Pradesh			
Kumaon Hills	1910, 1912	"	Not known
Himachal Pradesh			
Mandi	1909	"	Well established
Kulu	1909	"	Well established
Kangra	1911	Kulu	Perished in 1947
Chamba	1919	Kulu	Perished in 1947
Mahasu	1915	Kashmir	Well established
Kinnaur	1963	Kashmir	Well established

and Kangra valleys. Plantings in the Uttar State appear to have met with failure. The result of introductions to Jammu in 1963, and NEFA in 1966 have not yet been appraised.

CEYLON

Although records of the earliest plantings were reported to have been lost, approximately 20 brown trout (*Salmo fario*) were liberated in a small stream crossing the plain of Nuwara Eliya in 1892 (Fowke, 1938). Ova of unrecorded origin were imported each year between 1886 and 1889, their disappearance leading to further importations in 1892 and 1893. Brown trout were known to breed only occasionally during exceptionally cold years and for this reason were always "under control" (Fowke, 1938). Fowke further implies that with the failure of brown trout breeding, the culture and distribution of the naturally reproducing rainbow trout, *Salmo gairdneri* (Richardson), have flourished.

WEST PAKISTAN

A report of brown trout within 200 km of the Kashmir border lacks confirmation. However, proximity of the flourishing Kashmir populations would offer substantial evidence in favour of the report.

JAPAN

Importation of "trout" from the United States took place prior to 1900 (Jordan and Snyder, 1902). Brown trout are presently reared in two research laboratories and two hatcheries from which limited plantings are made to

FIG. 3. Naturalized distribution of *Salmo trutta* in South Central Asia.

local waters, although the species is not valued by the Japanese (Shiraishi, personal communication). The only known naturalized population of brown trout exists in Chuzenji Lake, Nikko City, Tochigi Pref.

NORTH AMERICA

UNITED STATES OF AMERICA

The original plantings of brown trout into North America came from eggs sent from Germany to New York by Herr Von Behr during the winter of 1883. These eggs were hatched at the Northville Hatchery, Michigan, and the fry released in early April in the Pere Marquette River of northern Michigan (Mather, 1889; Goode, 1903). Limited success followed a second shipment

of Von Behr trout which were again incubated at the Northville Hatchery, and at the Caledonia Hatchery, New York. Further shipments of eggs from Germany between 1884 and 1887 were reared in hatcheries at Cold Spring Harbour and Caledonia, New York; Northville, Michigan; Central Station, Washington; and Wytherville, Virginia (Smiley, 1884). Shipments of German ova were sent, also, to hatcheries in Pennsylvania and New Hampshire (Smiley, 1889a) and by 1897 eggs had been received by hatcheries in California (Anonymous, 1897).

The Loch Leven variety was first imported to the United States in 1885 (Smiley, 1889b). From this first shipment, ova were immediately transferred to hatcheries in Maine, New Hampshire, Iowa, and Minnesota. By 1887 they were being held in hatcheries extending from the states of Maine, Maryland, and Illinois in the east to Colorado and California in the west (Anonymous, 1897). However, because of numerous hatchery transfers, the identity of the German and Loch Leven varieties was soon lost (Miller and Alcorn, 1945).

Apparently more tolerant of environmental conditions than the native brook trout (*Salvelinus fontinalis* Mitchill), the brown trout was accused of serious competition with the former species and a precedent was set in 1906 when New York State sharply reduced the magnitude of its brown trout propagation (Bean, 1906).

In spite of the action of most government agencies in following the policy established by New York State, a survey of all states agencies in 1967 indicates that brown trout were ultimately introduced into 45 of the 50 American states (Table II). In the 34 states which now have naturalized populations in some waters within their boundaries (Fig. 4) all plantings had been made prior to 1936. Although no known naturalized populations of brown trout exist in Delaware, Indiana, Illinois, Missouri, and North Dakota, stocking programs continue. In Florida, Kansas, Oklahoma, Ohio, Kentucky, and Hawaii, failure in naturalization resulted in discontinuation of plantings. Texas, Louisiana, Mississippi, Alabama, and Alaska have never attempted brown trout introductions.

Canada

The first introduction to North America of the Loch Leven trout occurred in 1884 when 100,000 ova were shipped from the Howietoun hatchery in Scotland to Newfoundland (Anonymous, 1887; Catt, 1950). The first of the German brown trout to reach mainland Canada came from New York State and were planted in Lac Brule, Quebec, in 1890 (Catt, 1950). A recent survey indicates that although the dissemination of brown trout in Canada was slow and dependent on neighbouring American states, all provinces but Prince Edward Island and Manitoba and the Northwest and Yukon territories ultimately experienced successful introductions. Despite naturalization in 9 of the 10 provinces, Nova Scotia and Alberta remain as the only two presently conducting stocking programs (Table III).

TABLE II. Introductions and present status of the brown trout in the United States of America.

State	Year of introduction	Survival	Current stocking programme	Naturalized distribution
Alabama	None			
Alaska	None			
Arizona	Prior to 1930	Y[a]	Y	Y
Arkansas	Unknown	Y	N[a]	Y
California	1894–95	Y	Y	Y
Colorado	1887	Y	Y	Y
Connecticut	1899	Y	Y	Y
Delaware	1950	Y	Y	N
Florida	1956–57	N	N	N
Georgia	Unknown	Y	Y	Y
Hawaii	1935	N	N	N
Idaho	1915	Y	Y	Y
Illinois	1887	Y	Y	N
Indiana	Unknown	Y	Y	N
Iowa	1885	Y	Y	Y
Kansas	1951	N	N	N
Kentucky	1948	Y	N	N
Louisiana	None			
Maine	1885	Y	Y	Y
Maryland	Unknown	Y	Y	Y
Massachusetts	1887	Y	Y	Y
Michigan	1883	Y	Y	Y
Minnesota	1888	Y	Y	Y
Mississippi	None			
Missouri	Unknown	Unknown	Y	N
Montana	1889	Y	Occasional	Y
Nebraska	1889	Y	Y	Y
Nevada	1895	Y	Y	Y
New Hampshire	1887	Y	Y	Y
New Jersey	1900	Y	Y	Y
New Mexico	1893–94	Y	Y	Y
New York	1883	Y	Y	Y
North Carolina	1887	Y	Y	Y
North Dakota	Unknown	Y	Y	N
Ohio	Unknown	N	N	N
Oklahoma	1930's	N	N	N
Oregon	Early 1900's	Y	Y	Y
Pennsylvania	1886	Y	Y	Y
Rhode Island	Late 1930's	Y	Y	Y
South Carolina	Unknown	Y	Y	Y
South Dakota	Late 1880's	Y	Y	Y
Tennessee	Unknown	Y	Y	Y
Texas	None			
Utah	1900	Y	Y	Y
Vermont	Early 1890's	Y	Y	Y
Virginia	Unknown	Y	Y	Y
Washington	1935 and earlier	Y	Y	Y
West Virginia	1925–26	Y	Y	Y
Wisconsin	1887	Y	Y	Y
Wyoming	1933	Y	Y	Y

[a]Y = Yes; N = no.

Quebec and Newfoundland, the first provinces to introduce the brown trout, were also the first to withdraw from major stocking programs. As of 1954, brown trout existed only as planted fish in the North River, Terrebonne

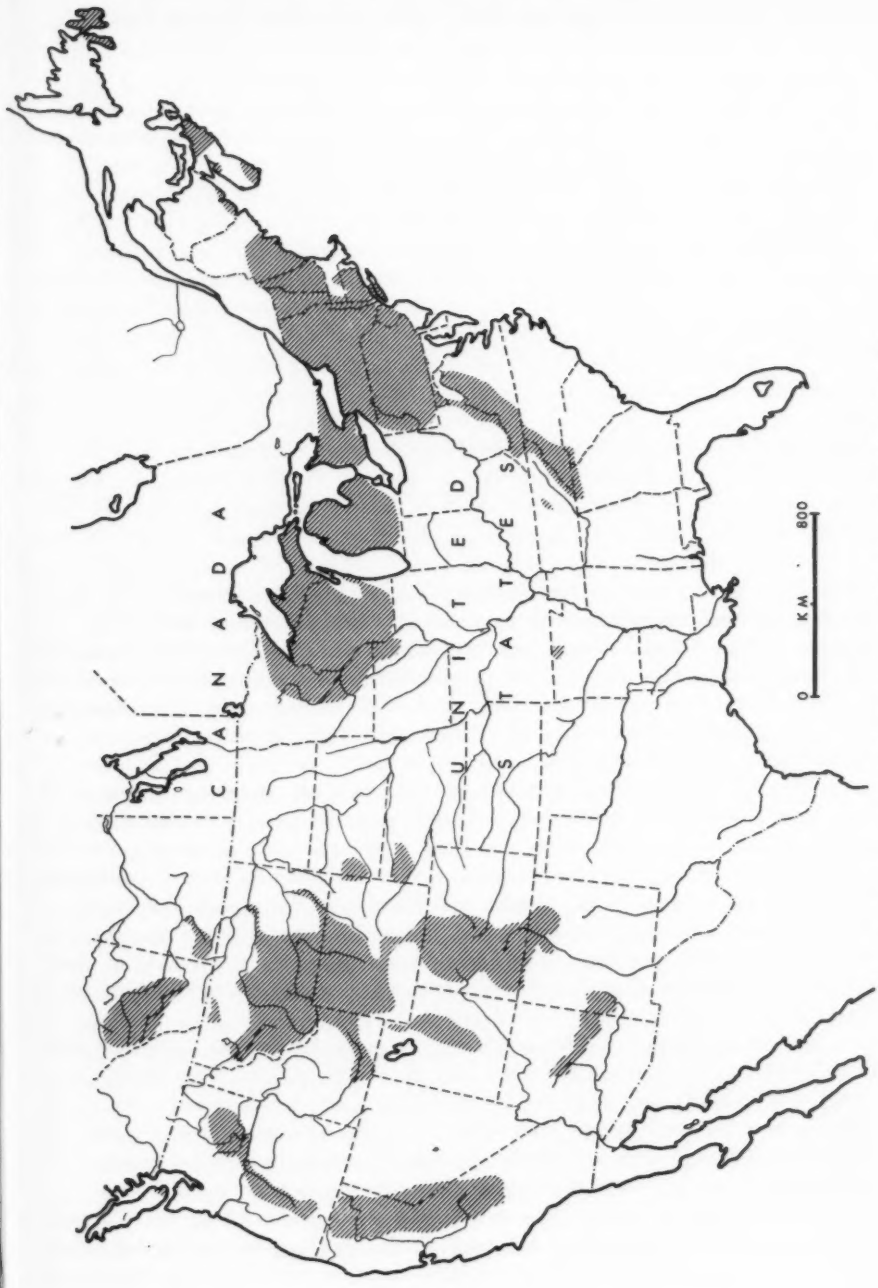


FIG. 4. Naturalized distribution of *Salmo trutta* in North America.

TABLE III. Introductions and present status of the brown trout in Canada.

Province or territory	Year of introduction	Source	Survival	Current stocking programme	Naturalized distribution
Alberta	1924	Montana	Y[a]	Y	Y
British Columbia	1932	Wisconsin, Montana	Y	N[a]	Y
Manitoba	1943	Washington	N	N	N
New Brunswick	1921	New York	Y	N	Y
Newfoundland	1884, 1892	Britain, Germany	Y	N	Y
Northwest Territories	None				
Nova Scotia	1925	Unknown	Y	Y	Y
Ontario	1913	Pennsylvania	Y	N	Y
Prince Edward Island	None				
Quebec	1890	New York	Y		
Saskatchewan	1924	Wisconsin, Montana	Y	N	Y
Yukon Territory	None				

[a]Y = yes; N = no.

County, and in Lake Memphremagog (Legendre, 1954). Stocking in Newfoundland was discontinued prior to the 1920's (Andrews, 1965) but the species is now widely distributed in southeastern Newfoundland especially on the Avalon Peninsula; it is also present in rivers and streams on the north side of Trinity Bay and on the Burin Peninsula. Well-established anadromous runs are also known in many of these areas. No authenticated reports are available for western or northern Newfoundland.

The Ontario Government developed an ambitious stocking program and distributed nearly 10 million fry, fingerling, and yearling brown trout to provincial waters between 1913 and 1962. Plantings were made primarily in waters marginal for the native brook trout. Distribution was discontinued after 1962 for a variety of reasons, the most important appearing to have been the low return of hatchery-reared fish realized by anglers (Mason, MS, 1961). Naturalized populations of brown trout presently occur only in river systems of southern Ontario that are tributary to lakes Huron, Erie, and Ontario.

In New Brunswick, brown trout of both Loch Leven and German origin were introduced to Saint John and Charlotte counties as early as 1921 (Catt, 1950). Catt noted, also, that excellent angling had been reported from these same waters. As well, brown trout had also been harvested in salt water off the Little Mis Pec River. Pelletier (personal communication) reports that naturalized populations now exist in the aforementioned counties.

Introductions to Saskatchewan in 1924 were primarily to the Cypress Hills region of southwest Saskatchewan. Early plantings in the Hudson Bay region were unsuccessful. The Cypress Hills plantings were continued annually

until 1934 (Wiggins, MS, 1960) and thereafter sporadically until discontinuation in the mid 1950's (Johnson, personal communication).

Nova Scotia and Alberta, the only two provinces still with stocking programs, both report widespread naturalized populations. As well, brown trout have been reported in estuarial waters off Nova Scotia (Prime, personal communication). The first introductions to Alberta's Raven River of the Red Deer system in 1924 and Carrot Creek of the Bow River system, 1925, resulted in a downstream dissemination which in the case of the latter, covered 141 km (Nelson, 1965). Plantings to date have distributed the brown trout and resulted in good angling in wide areas of the Saskatchewan and Athabaska watersheds (Paeta, personal communication).

Introductions to a few lakes of Jasper National Park, Alberta, in 1924 and 1942 were successful and resulted in natural populations. However, stocking was later discontinued and the fish poisoned, when deemed unpopular with the angler (Ward, personal communication).

In British Columbia, plantings of brown trout were made in the Cowichan and Little Qualicum River systems of Vancouver Island during the period 1932–35. Although spawning was noted in the former river system as early as 1937, natural populations made an insignificant contribution to the angler's catch (Carl et al., 1959). The practice of stocking brown trout was discontinued about 1961 (Northcote, personal communication).

In Manitoba, limited stockings between 1943 and 1961 failed to result in naturalized populations. As few stocked fish were captured by the angler, the rearing of brown trout was discontinued by 1962 (Kooyman, personal communication).

In spite of the limited naturalized distribution of the brown trout in Canada (Fig. 4), Dymond (1955) listed it and the carp *Cyprinus carpio* Linnaeus as the only two non-North American fishes in which introduction to Canadian waters proved to be significant.

Mexico

Information was not obtained for brown trout in Mexico. However, rainbow trout, *Salmo gairdneri*, are endemic to the mainland at elevations of 2000–2400 m above sea level (Needham and Gard, 1959). Successful introductions of rainbow trout were reported in tributaries of the Lerma and Amoloya Rivers of the high plateaus (Berriozabal, 1937). This evidence would probably support the hypothesis that brown trout habitat does exist in Mexico.

Puerto Rico

Brown trout ova were first imported to Puerto Rico around 1934. The eggs were reared to fingerlings and subsequently released in the Espiritu Santo River at El Yungue Forest. These and later introductions did not result in naturalized populations. Subsequently, stockings were discontinued by 1924 (Inigo, personal communication).

AFRICA

South Africa

The earliest importations of brown trout ova from the United Kingdom to Cape Town and Natal, South Africa, were made in 1876 (Hey, 1947). These and later importations made between 1881 and 1884 to Cape Town, King Williams Town, and the Drakensburg Mountains of Natal were failures. However, introductions of United Kingdom stock in 1890, 1892, and 1895, to cool mountain streams in the vicinity of the aforementioned areas, produced the present day naturalized populations (Smith, personal communication).

The establishment of two government hatcheries at Jonkershoek and Pirie, Cape Province, in 1893 and 1895 respectively, provided sources of brown trout for waters of the Transvaal and the Orange Free State, South Africa, and most of the nations of the south and eastern portion of the continent (Smith, personal communication; Harrison et al., 1963) (Table IV).

Table IV. Introductions and present status of the brown trout in Africa.

Country/province	Year: First introduction	Year: Successful introduction	Source	Survival	Current stocking programme	Naturalized distribution
South Africa						
Natal	1876	1890	U.K.	Y[a]	Y	Y
Cape Province	1876	1892	U.K.	Y	Y	Y
Transvaal	1903	1903	Cape Prov.	Y	Y	Y
Orange Free State	Unknown	Unknown	"	Y	Y	
Basutoland (Lisotho)	1904		"			
Kenya	1906	1921	U.K.	Y	Y	Y
Malawi		1907	Cape Prov.	Y		Y
Rhodesia	1907	1929	"	Y		Y
Tanzania	1934	1934	"	Y	Y	Unknown
Uganda	1930		U.K.	N[a]	N	N

[a]Y = yes; N = no.

Smith (personal communication) reported that because of a reduction in prime brown trout habitats, the species is less abundant than in earlier years. Also, he noted that rainbow trout, *Salmo gairdneri*, introduced locally have taken over marginal waters which once supported flourishing brown trout populations. However, limited hatchery production and plantings have continued in South Africa, particularly in impounded waters. Although growth is reported to be good in ponds and reservoirs, naturalization has not occurred (Department of Nature Conservation, 1964).

Eastern and Central Africa

All brown trout distributed in Eastern and Central Africa, except in Kenya and Uganda, although essentially of British origin, were from South African hatcheries.

The first importations were made into the waters of Basutoland (Lisotho) in 1904. Harrison et al. (1963) report that brown trout thrived and remained local to a number of large pools in the Langabeletsi, Quthing, Maseru, Sangabethu, and Mokhotlong rivers.

Successful introductions to Malawi (Nyasaland) of both brown and rainbow trout, were made in 1907 and 1908. A later importation and planting in 1932 was likely responsible for the establishment of a naturalized population in the Zamba Plateau (Harrison et al., 1963).

Rhodesia (Southern Rhodesia) attempted to introduce the brown trout in 1910, 1921, and 1924 but did not attain success until 1929 when populations were established in the streams of Inyanga, especially in regions with elevations of 1500–2300 m above sea level (Harrison et al., 1963).

Kenya experienced similar failures from 1906 and 1910 plantings but in 1921 established naturalized populations in waters of the Aberdare Mountains and Mount Kenya at minimum elevations of 2000 m above sea level (Harrison et al., 1963). Watson (personal communication) stated that the brown trout has proved less adaptable to local conditions than the introduced rainbow trout and, consequently, brown trout are now limited to about eight rivers on Mount Kenya and the Aberdare range. As well, a government trout hatchery, built in 1947, although still importing some 50,000 brown trout ova, now concentrates on annual productions of 250,000 rainbow trout ova.

Plantings of brown trout to waters of the Mount Elgon region of Uganda in 1930 failed and the project was discontinued (Semakula, personal communication). Plantings were made in streams of the Takukuya District of Tanzania (Tanganyika) in 1934 but continuous stocking has been considered necessary to maintain the species, as naturalized populations are questionable (Harrison et al., 1963).

The present naturalized distribution of brown trout in Africa (Fig. 5) is limited essentially to the rivers of mountainous regions and to eastern coastal streams of South Africa.

SOUTH AMERICA

Argentina

The introduction of brown trout (la trucha marron o europea) to Argentina from England began as early as 1904 when plantings were made in rivers in the vicinity of Santa Cruz (de Plaza and Plaza, 1949). Since that time, the species has become naturalized in nearly all of the rivers and large lakes of the Patagonian Steepe (Mastrarrigo, personal communication) (Fig. 6).

Chile

Brown trout eggs were first brought to Chile in 1905 from Hamburg, Germany, and placed in streams between 33° and 41°S lat (Astete, personal communication).

The present naturalized distribution of brown trout (Fig. 6) is more or less continuous between 30° and 42°S lat with only a few isolated populations

FIG. 5. Naturalized distribution of *Salmo trutta* in Africa.

beyond this range (Astete, personal communication). However, the dispersal of fish from three Government hatcheries maintains standing populations of the species between 19° and 55°S lat where the brown trout are considered to be one of Chile's richest fisheries resources.

PERU

Introductions of salmonids to Peru did not occur until 1928 (Tovar S., personal communication). Although the source or date of introduction of brown trout is unavailable, Tovar S. (personal communication) indicates that they are held in a trout culture station at Chucuito, State of Puno, and naturalized in the lakes and rivers of the same state at or above an elevation of 2500 m above sea level. Trout culture (although not necessarily brown trout) is also conducted in five other states encompassing elevated regions of the Andes. The hatcheries distribute trout, including the best adapted species, the rainbow trout, to the lakes and rivers of the various National Parks (Tovar S., personal communication).

Brown trout have not been introduced into Colombia where rainbow trout thrive (Gomez, personal communication). No evidence of the presence of brown trout in other countries of the Andes has been obtained. However,

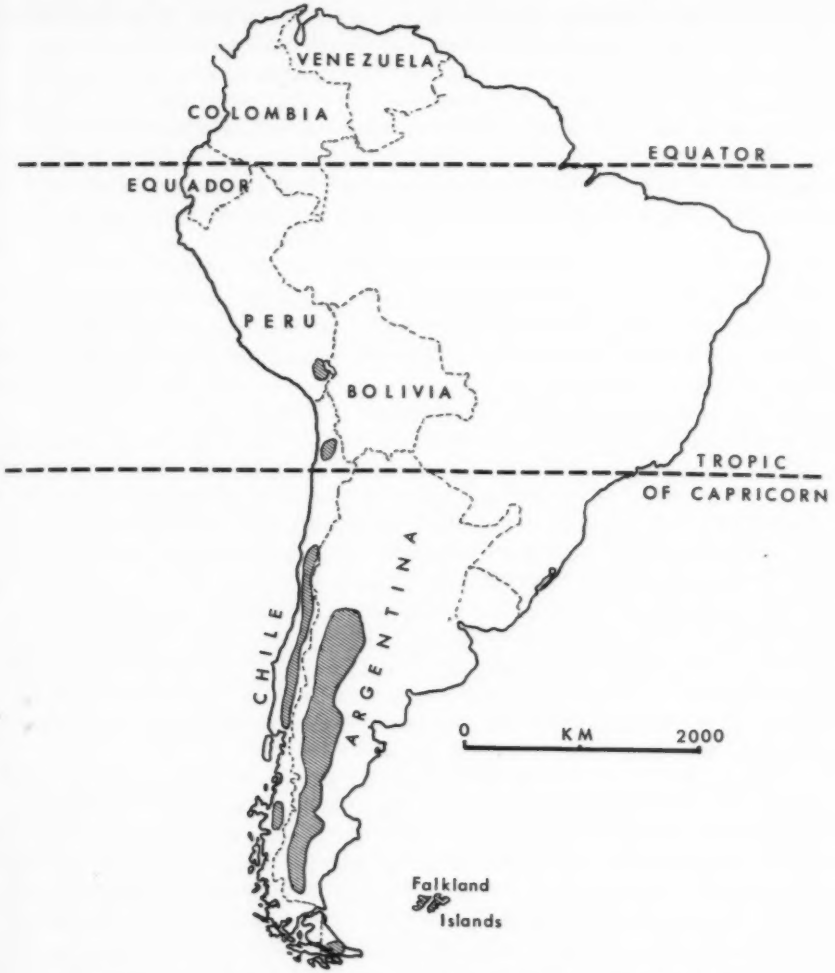


FIG. 6. Naturalized distribution of *Salmo trutta* in South America.

the naturalization of rainbow trout in Ecuador in the 1930's (Howard and Godfrey, 1950) and brook trout *Salvelinus fontinalis* (Mitch.), in the Cordillera of Merida, Venezuela (Werbezahn, personal communication) supports the possibility that brown trout may be scattered throughout the length of South America.

THE FALKLAND ISLANDS

Although the early records of the introduction of brown trout to the Falkland Islands were lost in a fire, the first attempts at introduction were

made apparently during World War II (Arrowsmith and Pentelow, 1965). In 1947, 30,000 brown trout ova listed as *Salmo fario* were received as a gift from the Chilean Government. Most of the shipment was stocked as fry into rivers of East Falkland. From 1948 through 1952, when stocking was discontinued, 55,000 ova of lake origin were flown from Great Britain to Stanley and subsequently distributed to waters in both the East and West Falklands. Angler's returns since 1954 indicate the presence of natural reproduction and a resultant sea run population (Arrowsmith and Pentelow, 1965).

DISCUSSION

Dissemination of the European brown trout appears to have been so complete in the past 100 years that most areas of the world capable of supporting significant natural populations have now received introductions. Discontinuity or limitation in range is typical, however, on all continents where the species has become naturalized.

The most important ecological factor limiting the endemic geographical distribution of salmonoid fishes appears to be water temperature (Vladykov, 1963). Brett (1956) states that not only are temperature extremes important to the life of fish but also that moderate extremes may effect an inability to feed, resist diseases, reproduce successfully, and be sufficiently active in the face of competition and predation, thus causing death.

An examination of mean air temperature, which may be considered to approximate adequately water temperatures (Weatherley, 1963), reveals that mean air temperatures (Dent, 1936) not exceeding 27 C in July nor dropping below −17 C in January characterize the native range of brown trout. Further, a cold temperate climate prevails with substantial autumn and winter precipitation in the form of rain or snow.

Thermal tolerance limits for brown trout have been reported by several workers. Fry (1947) gives an upper incipient lethal temperature of between 25 and 27 C. Gardner and Leetham (1914) record the death of brown trout held at temperatures above 25 C. However, thermal requirements in the embryological stage would seem more critical than in fully developed fish. Embody (1934) gives a water temperature range of 1.9–11.2 C as that within which brown trout eggs were observed to hatch in nature. Gray (1928) states that eggs of the species can be incubated between 2.8 and 13 C and excessive mortality occurs about 15 C. Brown trout, of course, live in natural waters during cold weather at temperatures as low as 0 C.

Ferguson (1958) found that the preferred temperature of brown trout ranged between 12.4 and 17.6 C in fish living in a thermal gradient over a 2-year period. Although the optimum temperature for growth may approximate the preferred temperature, Swift (1961) reports a temperature of 12 C and Brown (1957) concludes that there are two ranges: 7–9 C and 16–19 C. Differences in thermal acclimation would seem a likely explanation for these phenomena. The ability of the brown trout, unlike many species, to exhibit peak metabolism at temperatures approaching the upper incipient lethal

temperature (Fry, 1947) would indicate that the brown trout is capable of thriving over a wide range of ambient water temperatures.

Areas of the world with naturalized brown trout populations have, as might be expected, temperature regimes similar to those of the native range. Resident populations of the species in Australia and New Zealand occur only in areas characterized by a damp temperate climate at elevations of 300 m or more above sea level. The growth rate of brown trout in New South Wales and Tasmania was found by Weatherly and Lake (1967) to exceed rates in the Lake District of England.

In South America, the naturalization of brown trout has occurred in areas typified by air temperatures reaching a maximum of 21 C in summer (January) and not exceeding 10 C in winter. The extensive elevated areas of the Cordillera of the Andes and Patagonia account for the presence of brown trout along the continental divide.

In North America, despite a wealth of native trout and char, the brown trout has become naturalized over an extensive area characterized by damp temperate to wet winter climates. The northern limit of the range follows closely a mean minimum daily air temperature in January of −12 C and a snow cover of no less than 2.5 cm extending over an annual mean maximum of 140 days. Plantings of brown trout further northward in parts of Saskatchewan and Ontario failed to establish known naturalized populations.

The southern limit of range of the brown trout in North America appears to be restricted by summer air (July) temperatures in excess of 21 C. However, range extensions into warmer areas where July temperature may reach 27 C have occurred in elevated areas of the Appalachian, Ozark, Cascade, Rocky, and Wasatch mountains. As in Africa, brown trout in North America inhabit waters in warmer regions including the Wasatch Mountains and Colorado plateau, but are limited to heights of 2000 ft or more above sea level.

Ecological factors other than temperature may be expected to limit the survival of planted fish or the establishment of naturalized populations. The absence of satisfactory spawning grounds, particularly in lowland reaches of streams where the fish have often been planted, may prevent the production of progeny especially if natural or artificial barriers prevent the upstream movement of mature fish to suitable breeding grounds. Likewise, the microhabitat may not provide the cover necessary for young or adult fish. Sporadic flooding may destroy spawning beds or microhabitat and, as in Chambe, India (Tripathi, personal communication) may completely displace the fish. Also, seasonal or permanent availability of food, predator–prey relationships, and physical and chemical factors, alone or in combination, may have significant effects on survival (Weatherly, 1963).

Although several studies have been undertaken on populations of brown trout in Great Britain (Horton, 1961; Thomas, 1964), New Zealand (Hobbs, 1948; Allen, 1951), Australia (Lake, 1957; Nicholls, 1958), and North America (McFadden and Cooper, 1962, 1964; Marshall, MS, 1968), specific differences in ecological requirements between this species and other stream-spawning salmonids are not clearly defined.

Perhaps the best evidence of ecological differences comes from the relative success of introductions of brown, brook, and rainbow trout to the waters of foreign countries. In New Zealand (Allen, 1956) where brown and rainbow trout have been disseminated to most rivers, the brown trout dominated in the South Island whereas the rainbow trout generally failed to establish itself. On the North Island, brown trout predominated to the south of a line from "Southern Hawke's Bay to north Taramaki," rainbow trout to the north of the line, and neither species was dominant along the line. Allen (1956) stated that the reason for this precise distribution was not known.

In streams of Natal, South Africa, into which brown trout were the first trout species introduced, later introductions of rainbow trout generally failed (Crass, 1964). However, Crass (1964) stated that for unknown reasons well-established populations of brown trout in the Polela River were displaced by introduced rainbow trout. In Sweden (Nilsson, 1967), plantings of brook and rainbow trout into the endemic waters of brown trout were largely unsuccessful. Similarly in France (Vivier, 1955, cited in Nilsson, 1967) attempts to acclimate brook and rainbow trout failed except in areas where brown trout were absent.

In North America, brown trout have been planted generally in waters considered to be marginal or unsuitable for native trout or char. The apparent failure of many plantings over the past eight decades to establish worthwhile naturalized populations and, as a consequence, the discontinuous distribution of the species across the continent may be attributed, in part at least, to unfavourable aquatic environments in which hatchery-reared brown trout were expected to survive and reproduce. Evidence of both the coexistence of brown trout with other salmonids and the displacement of brook and rainbow trout (Bean, 1906; Brynildson et al., 1964; Dymond, 1955) where such plantings have been made in streams, ponds, and lakes suggests that brown trout would be expected to become widely naturalized if introduced into numerous North American trout and char waters from which it has intentionally been excluded.

Any major future expansion in the world distribution of the brown trout, with the possible exception of Asia, is unlikely. Climate restrictions would seem to be of singular importance in defining the general range of the species on all continents. Because of a general disinterest in brown trout in countries which have other indigenous salmonids, and a general preference for the rainbow trout on continents where the two exotics have been established, there is no evidence of enthusiasm among fisheries managers to engage actively in further disseminating the brown trout to local waters.

REFERENCES

ALLEN, K. R. 1951. The Horokiwi stream, a study of a trout population. N.Z. Marine Dept. Fish. Bull. No. 10. 238 p.

1956. The geography of New Zealand's freshwater fish. N.Z. Sci. Rev., **14**(3): 3–9.

AMERICAN FISHERIES SOCIETY. 1960. A list of common and scientific names of fishes from the United States and Canada. Spec. Publ. No. 2. 102 p.

ANONYMOUS. 1887. Fish culture in Scotland. Bull. U.S. Fish. Comm., **6**: 408.
1897. Report of the Commissionner of Fisheries. House Doc., Vol. 59, 55th Congress (1897–98).

ANDREWS, C. W. 1965. Early importation and distribution of exotic freshwater fish species in Newfoundland. Canadian Fish Culturist, No. 35. p. 35–36.

ARROWSMITH, SIR E., AND F. T. K. PENTELOW. 1965. The introduction of trout and salmon to the Falkland Islands. Salmon Trout Mag. No. 174. p. 119–129.

BEAN, T. H. 1906. Discussion period of thirty-fifth annual meeting of American fisheries society. Trans. Am. Fish. Soc., **35**: 137.

BEAN, T. M. 1888. The distribution and some characters of the salmonidae. Am. Naturalist, **22**: 306–314.

BERG, L. S. 1932. Les poissons des eaux douces de l'U.R.S.S. et des pays limitrophes. 3 ed. Leningrad.

BERRIOZABAL, F. P. 1937. The management of fish hatcheries in Mexico. Trans. Am. Fish. Soc., **67**: 94–95.

BRETT, J. R. 1956. Some principles in the thermal requirements of fishes. Quart. Rev. Biol., **32**(2): 75–87.

BROWN, M. E. 1957. Experimental studies on growth, 1. *In* M. E. Brown [ed.] The physiology of fishes. Academic Press, Inc., New York. p. 361–400.

BRYNILDSON, O. M., V. A. HACKER, AND T. A. KLICK. 1964. Brown trout. Its life history, ecology and management. Wisconsin Conserv. Dept. Publ. No. 234. 14 p.

CARL, G. C., W. A. CLEMENS, AND C. C. LINDSAY. 1959. The freshwater fishes of British Columbia. British Columbia Provincial Museum, Handbook No. 5. Victoria, B.C.

CATT, J. 1950. Some notes on brown trout with particular reference to their status in New Brunswick and Nova Scotia. Canadian Fish Culturist, No. 7. 25–27.

CRASS, R. S. 1964. Freshwater fishes of Natal. Shuter, Pietermasitzburg. 167 p.

DAHL, K. 1918. Studies of trout and trout waters in Norways. I. Salmon Trout Mag. No. 17. p. 58–79.
1919. Studies of trout and trout waters in Norway. II. Ibid. No. 18. p. 16–33.

DENT, J. M. 1936. Dent's Canadian school atlas. J. M. Dent and Sons (Canada) Ltd., Toronto, Ont. 71 p.

DEPARTMENT OF NATURE CONSERVATION OF PROVINCIAL ADMINISTRATION OF THE CAPE OF GOOD HOPE. 1966. Rept. Div. Inland Fish. p. 48–64.

DYMOND, J. R. 1955. The introduction of foreign fishes in Canada. Proc. Intern. Assoc. Theoret. Appl. Limnol., **12**: 543–553.

EMBODY, G. C. 1934. Relation of temperature to the incubation periods of eggs of four species of trout. Trans. Am. Fish. Soc., **64**: 281–292.

FERGUSON, R. G. 1958. The preferred temperature of fish and their midsummer distribution in temperate lakes and streams. J. Fish. Res. Bd. Canada, **15**(4): 607–624.

FOWKE, P. 1938. Trout culture in Ceylon. Ceylon J. Sci., Sect. C, Fish. Bull., Ceylon Fish. No. 6. 78 p.

FROST, W. E., AND M. E. BROWN. 1967. The trout. Collins, St. James's Place, London. p. 55–61.

FRY, F. E. J. 1947. Temperature relations of salmonids. Proc. Natl. Comm. Fish Culture, 10th meeting, App. "D."

GARDNER, J. A., AND C. LEETHAM. 1914. On the respiratory exchange in fresh water. I. On brown trout. J. Biochem., **8**: 374–390.

GOODE, G. B. 1903. American fishes. Dana Estes and Co., Boston, Mass. 496 p.

GRAY, J. 1928. The growth of fish. III. The effect of temperature on the development of eggs of *Salmo fario*. J. Exptl. Biol., **6**(2): 125–130.

GÜNTHER, A. 1866. Fishes of the British Museum No. 6. p. 104.

HARRISON, A. C., K. E. SHORTT-SMITH, J. H. YATES, R. A. JUBB, G. RUSHBY, AND C. T. FLAMWELL. 1963. Freshwater fish and fishing in Africa. Thomas Nelson and Sons (Africa) (Ptg.) Ltd. 210 p.

HEY, D. 1947. The fertility of brown trout eggs at the Jonkershoek Inland Fish Hatchery. Trans. Am. Fish. Soc., **77**: 26–31.

HOBBS, D. F. 1948. Trout fisheries in New Zealand, their development and management. Marine Dept., Fish. Bull. No. 9. 175 p.

HORTON, P. A. 1961. The bionomics of brown trout in a Dartmoor stream. J. Animal Ecol., **30**(2): 311–338.

HOWARD, G. V., AND E. R. GODFREY. 1950. Fishery research and educational institutions in North and South America. Spec. Publ. Food Agr. Organ. U.N., Washington, U.S.A. 85 p.

HUBBS, C. L. 1930. The specific name of the European trout. Copeia, No. 172: 86–89.

JORDAN, D. S. 1926. The name of the brook trout in Europe. Ibid., No. 155: 140–141.

JORDAN, D. S., AND J. O. SNYDER. 1902. A review of the salmonid fishes of Japan. Proc. U.S. Natl. Museum, **24**: 567–593.

LAKE, J. S. 1957. Trout populations and habitats in N.S.W. Australian J. Marine Freshwater Res., **8**(4): 414–450.

LEGENDRE, V. 1954. Key to game and commercial fishes of the Province of Quebec. The freshwater fishes. Vol. I. Game Fish. Dept., Prov. Quebec. 180 p.

MARSHALL, T. L. MS, 1968. Salmonid populations and exploitation in the upper Sydenham River, Ontario. M.Sc. Thesis. Univ. Guelph, Guelph, Ont. 84 p.

MASON, R. E. MS, 1961. Fish hatcheries, their present status and potential. District Rept. Ont. Dept. Lands Forests, Hespeler, Ont. 17 p.

MATHER, F. 1889. Brown trout in America. Bull. U.S. Fish. Comm., **7**: 21–22.

MCFADDEN, J. T., AND E. L. COOPER. 1962. An ecological comparison of six populations of brown trout (*Salmo trutta*). Trans. Am. Fish. Soc., **91**(1): 53–62.
1964. Population dynamics of brown trout in different environments. Physiol. Zool., **37**(4): 355–363.

MILLER, R. R., AND J. R. ALCORN. 1945. The introduced fishes of Nevada, with a history of their introduction. Trans. Am. Fish. Soc., **73**: 173–193.

NEEDHAM, P. R., AND R. GARD. Rainbow trout in Mexico and California with notes on the cutthroat series. Univ. Calif. Press, Berkeley, Calif. 124 p.

NELSON, J. S. 1965. Effects of fish introductions and hydroelectric development on fishes in the Kananaskis River system, Alberta. J. Fish. Res. Bd. Canada, **22**(3): 721–753.

NICHOLLS, A. G. 1958. The population of a trout stream and the survival of released fish. Australian J. Marine Freshwater Res., **9**: 319–350.

NIKOLSKII, G. V. 1937. The trout of middle Asia. Salmon Trout Mag. No. 86. p. 76–81.
1961. Special Ichthyology. Published for the Natl. Found., Washington D.C. and the Smithsonian Inst., by the Israel Program for Sci. Trans., Jerusalem. 538 p.

NILSSON, N. A. 1967. Interactive segregation between fish species. *In* S. D. Gerking [ed.] The biological basis of freshwater fish production. Black Sci. Publ., Oxford. p. 295–313.

PAVESI, P. 1887. Notes on hatching and planting young fish in Italian waters. Bull. U.S. Fish. Comm., **6**: 263–265.

DE PLAZA, M. L. F., AND J. C. PLAZA. 1949. Salonicultura. Republica Argentina, Min. Agr. Yanderia, Publ. Misc. No. 321.

REGAN, C. T. 1911. The freshwater fishes of the British Isles. Methuen & Co., London. p. 54–72.

ROUGHLEY, T. C. 1951. Fish and fisheries of Australia. Augus and Robertson, Sydney.

SEELEY, H. G. 1886. The fresh water fishes of Europe. Casswell and Co., London.

SKRYNSKI, W. 1967. Freshwater fishes of the Chatham Islands. N.Z. J. Marine Freshwater Res., **1**(2): 89–98.

SMILEY, C. W. 1884. Brief notes upon fish and fisheries. Bull. U.S. Fish. Comm., **4**: 359–368.
1889a. Notes upon fish and fisheries. Ibid., **7**: 33–47.
1889b. Loch Leven trout introduced in the United States. Ibid., **7**: 28–32.

SWIFT, D. R. 1961. Communications in Director's report. Rept. Freshwater Biol. Assoc. Brit. Empire No. 29.

TCHERNAVIN, V. 1939. The origin of salmon. Is its ancestry marine or fresh water? Salmon Trout Mag. No. 95. p. 120–140.

THOMAS, J. D. 1964. Studies on the growth of trout, *Salmo trutta* from four contrasting habitats. Proc. Zool. Soc. London, **142**(Pt. 3): 459–510.

VIVIER, P. 1955. Sur l'introduction des Salmonides exotiques en France. Verh. Intern. Ver. Limnol., **12**: 527–535.

VLADYKOV, V. D. 1931. Poissons de la Russie Sous-Carpathique (Tchecoslovaquie). Mem. Soc. Zool. France, **29**(4): 217–374.
1963. A review of salmonid genera and their broad geographical distribution. Trans. Roy. Soc. Canada, **1** (ser. 4): 459–504.

WEATHERLEY, A. H. 1963. Zoogeography of *Perca fluviatilis* (Linnaeus) and *Perca flavescens* (Mitchill) with special reference to the effects of high temperature. Proc. Zool. Soc. London, **141**(Pt. 3): 557–576.

WEATHERLEY, A. H., AND JOHN S. LAKE. 1967. Introduced fish species in Australian inland waters. *In* A. H. Weatherley [ed.] Australian inland waters and their fauna. Australian Natl. Univ. Press. p. 217–239.

WIGGINS, W. B. G. MS, 1959. The introduction and ecology of the brown trout, *Salmo trutta* Linnaeus, with special reference to North America. M.A. Thesis. Univ. Toronto, Toronto, Ont. 109 p.

PERSONAL COMMUNICATIONS CITED

ASTETE, R. B. 1967. Departamento de pesca y caza, Santiago, Chile.

GOMEZ, L. 1967. Ministerio de Agricultura, Seccion de Caza y Pesca, Bogota, Columbia.

HAYSOM, N. W. 1967. Department of Harbours and Marine, Brisbane, Queenlands, Australia.

INIGO, F. 1967. Division of Fish and Wildlife, Department of Agriculture, San Juan, Puerto Rico.

JOHNSON, R. P. 1967. Fisheries Laboratory, University of Saskatchewan, Saskatoon, Sask.

KOOYMAN, B. 1967. Department of Mines and Natural Resources, Winnipeg, Man.

LAKE, J. S. 1967. University of Sydney, Sydney, New South Wales.

LITTLE, R. W. 1967. New Zealand Marine Department, Wellington, New Zealand.

LYNCH, D. D. 1967. Inland Fisheries Commission, Hobart, Tasmania.

MASTRARRIGO, V. 1967. Department de Piscicultura y Pesca interior, Buenos Aires, Argentina.

NORTHCOTE, T. G. 1967. Institute of Fisheries, University of British Columbia, Vancouver, B.C.

PAETZ, M. J. 1967. Department of Lands and Forests, Calgary, Alberta.

PELLETIER, A. T. 1967. Fish and Wildlife Branch, Department of Lands and Mines, Fredericton, New Bruwnsick.

PRIME, M. 1967. Department of Lands and Forests, Halifax, Nova Scotia.

SEMAKULA, S. N. 1967. Fisheries Department, Entebbe, Uganda.

SHIRAISHI, Y. 1967. Freshwater Fisheries Research Laboratory, Nikko Branch, Japan.

SMITH, D. F. 1976. Department of Nature Conservation, Stellenbosh, South Africa.

TONBRIDGE, B. R. 1967. Fisheries and Wildlife Department, Melbourne, Victoria.

TOVAR, S. A. 1967. Universidad Agraria, La Molina, Peru.

TRIPATHI, S. D. 1967. Central Inland Fisheries Research Institute, BarrackPore, India.

WARD, J. C. 1967. Department of Indian Affairs and Northern Development, Calgary, Alberta.

WATSON, C. E. P. 1967. Fisheries Department, Nairobi, Kenya.

WERBEZAHAN, F. H. 1967. Universidad Central de Venezuela, Caracas, Venezuela.

Interrenalectomy and Stress in Relation to Some Blood Components of an Elasmobranch (*Raja radiata*)[1]

By D. R. Idler and B. J. Szeplaki

Fisheries Research Board of Canada
Halifax Laboratory, Halifax, N.S.

ABSTRACT

From the literature there was a doubt as to whether interrenalectomy would result in elevated plasma potassium levels in a elasmobranch; in this study, no elevation was observed by comparison with sham-operated thorny skate (*Raja radiata*) held in sea water for up to 44 days post-operative.

Blood calcium levels were significantly elevated in the interrenalectomized animals between 13 and 23 days but the increase was only 10%.

There was no change in osmolality, sodium chloride, magnesium, or urea which can be attributed to interrenalectomy. Noteworthy was the manner in which both sham and interrenalectomized animals were able to maintain plasma electrolyte levels during the long period of starvation after surgery. Whenever significant changes occurred during the course of the experiment, sham and interrenalectomized fish were similarly affected, apart from the exception noted for calcium.

Plasma urea levels were significantly depressed after interrenalectomy when the skates were held in a 3:1 mixture of sea water: fresh water for 7–9 days. The same trend was observed for sham-operated animals but the decrease was not significant. Normal animals maintained plasma urea in 75% sea water but not in 60% sea water.

INTRODUCTION

Nearly 4 years ago we began an investigation to study the function of corticoids in elasmobranchs. Cortisol, corticosterone, or both, had been reported to be present in microgram quantities in the blood of numerous species (Chester Jones and Phillips, 1960). It was our intention to approach this problem by testing the working hypothesis that interrenalectomy would reduce blood corticoid levels to negligible amounts. It was here that we encountered our first obstacle for we could not find microgram amounts of either cortisol or corticosterone in the blood of *Raja radiata* or *R. ocellata*. We had selected the first of these species because it generally has a compact interrenal most frequently encountered on the left side of the animal. In due course, the principal corticoid in these species was shown to be the hitherto undescribed 1α-hydroxycorticosterone. Subsequent study has shown that this steroid occurs in all 13 species of elasmobranchs investigated to date (Truscott and Idler, 1968). It has also been shown to be a potent mineral corticoid for the rat (Idler et al., 1967). It possesses good mineralocorticoid activity in the toad bladder bioassay (unpublished data). Our attention was now directed again

[1]Received for publication August 2, 1968.

J. Fish. Res. Bd. Canada, 25(12): 2549–2560, 1968.
Printed in Canada.

to an assessment of the functions of the corticoid, 1α-hydroxycorticosterone, in *R. radiata*.

It was decided that there was little to be gained from injecting the steroid into an animal with a functioning interrenal. In 1941, Hartman and his co-workers described the normal levels of several inorganic ions, urea, and sugar in the blood of *R. erinacea* and followed this (Hartman et al., 1944) with a study on the effect of interrenalectomy on these constituents. Although certain changes were apparent after interrenalectomy it was concluded that there was no statistically significant difference between the interrenalectomized and the sham-operated animals and therefore there was no evidence that the interrenals played any role in regulating plasma electrolytes. Likewise, there was no change in blood sugar but the authors did conclude that there was a decrease in liver glycogen. However, Chester Jones (1957) analyzed these data statistically and concluded "..... the whole problem needs re-investigation but there is an indication that removal of the interrenal in the skate is followed by an increased plasma potassium value as adrenalectomy normally is in eutherians." The suggested reinvestigation was a primary purpose of this study.

MATERIALS AND METHODS

In the principal experiment observations were made on 12 specimens (6 ♀, 6 ♂) of *R. radiata*, ca. 18–22-inch wing span. These animals were caught in local waters off Nova Scotia, and were held in large tanks (1.15 m depth) of circulating 100% sea water at 8 C. All animals would not take food equally well, so all were fasted during the experiment. Skates were tagged, anaesthetized with tricaine methane sulphonate (Kent Chemicals, Vancouver, B.C.) and were shammed or interrenalectomized after 1 week in captivity (3 ♀, 3 ♂ interrenalectomized, 3 ♀, 3 ♂ shammed). Interrenalectomy was performed from the dorsal surface and the incision was made immediately posterior to the pelvic girdle and ventral to the spinal column. Although the gland generally lies on the left side, both sides were operated to assure that all interrenal tissue was removed. In sham animals, incisions were made to expose the gland. There was very little bleeding in any of the 12 animals around the area of the kidney and the sutures remained intact in all animals.

Blood samples (1.5–2 ml) were taken from the central caudal vein, at ca. 7-day intervals. Samples were collected in syringes rinsed with 1% lithium heparin, centrifuged, and the plasma quick-frozen in small sealed vials on dry ice/acetone and stored on dry ice; no hemolysis occurred.

The first death occurred 14 days after interrenalectomy, followed by two interrenal and two sham deaths 21–36 days post-operative. Seven animals survived ca. 60 days at which time they were killed. All interrenalectomized fish were thoroughly examined post-mortem for any remaining or regenerated interrenal tissue and none was found.

Osmolality was determined on 0.2 ml plasma, using a commercial osmometer (Advanced Instruments Inc.). Urea was quantified colorimetrically

after treatment with urease (Kit No. TC-UR-I, Mannheim Boehringer Corp.); the method was modified for use with 20 λ plasma. Sodium and potassium were determined by flame photometry (Model 143, Instrumentation Laboratory Inc.) Plasma (0.2 ml) was diluted with lithium diluent (containing 15 mEq/liter lithium ion). The standard contained 300 mEq/Na^+ and 8 mEq/liter K^+. Chloride concentrations were found by the method of Klein (1958), modified to employ 0.33 ml plasma. Calcium and magnesium were determined with a Unicam Absorption Spectrophotometer, Model No. S.P. 90. Plasma (0.1 ml) was diluted according to the method of Quinn et al. (1965).

Statistical evaluation of data was carried out using the Student's *t*-test and differences were considered significant when $P = \text{or} < 0.05$.

Experiments (34 animals) similar to the above were carried out for various periods of time prior to, and after, this main investigation and similar results were obtained.

Urea values were determined by titration method (Van Slyke and Cullen, 1954) interrenalectomized, sham, and "normal" animals which were kept in sea water–fresh water mixtures containing 20, 33, 50, 60, and 75% sea water. These tests were run for varying time periods.

Other exploratory experiments of a few hours duration were conducted to determine any differences in animals under distressing conditions as contrasted with the relatively "ideal" environmental surroundings to which skate were subjected in the principal experiment; variables examined were salinity and temperature. For example interrenalectomized and sham animals were taken 2 days post-operatively from 100% salt water and placed directly in freshwater for 1 hr. Blood samples were taken from the animals prior to surgery, before transfer to fresh water and after 1 hr in fresh water.

In other experiments, interrenalectomized and sham animals were subjected 2 days post-operatively to a sudden temperature shock of +11 C (1–12 C) for 1 hr; plasma samples were taken as above and Ca^{++}, Mg^{++}, Na^+, K^+, and Cl^- were determined.

An experiment to measure the decrease of 1α-hydroxycorticosterone in the plasma of an interrenalectomized skate was carried out. The concentration was quantified by acid fluorescence after paper chromatography (Idler and Truscott, 1967). A mature male skate (*R. radiata*), 9.3 kg weight, was interrenalectomized and blood sampling (ca. 6 ml) was done pre-operatively and every 2 hr post-operatively over a period of 12 hr, followed by a total bleeding of the animal 24 hr after interrenalectomy at which time 72 ml blood were obtained.

RESULTS

There was no overlap in the standard error of the mean for plasma calcium values in the sham-operated and interrenalectomized animals on the 13th, 16th, and 23rd days (Table I). The mean plasma calcium level of the sham animals was 9 mEq/liter, and the interrenalectomized 10 mEq/liter during this period ($P < 0.005$). By the 9th day post-operative the calcium values

TABLE I. Changes in plasma of interrenalectomized (I) and sham-operated (S) *R. radiata*.

Plasma constituent	Treatment	Pre-operative	Post-operative Days 6	9	13	16	23	30	37	44
Osmotic pressure	I	960±5(6)	942±14(6)	944±7(6)	945±6(6)	943±4(5)	934±7(4)	939±3(3)	957±6(3)	1036±25(3)
(*mosmols/kg*)	S	958±5(6)	957±6(6)	941±4(6)	948±6(6)	940±5(6)	931±15(6)	933±9(5)	973±2(4)	1078±53(4)
Sodium	I	268±9(6)	290±6(6)	284±8(6)	248±4(6)	303±10(5)	290±5(4)	271±3(3)	277±9(3)	271±12(3)
(*mEq/liter*)	S	269±5(6)	302±5(6)	285±5(6)	244±6(6)	298±8(6)	292±10(6)	285±9(5)	274±4(4)	272±5(4)
Potassium	I	3.5±0.2(6)	3.2±0.3(6)	3.3±0.2(6)	2.5±0.4(6)	2.8±0.3(5)	3.3±0.2(4)	3.0±0.2(3)	2.9±0.1(3)	2.8±0.3(3)
(*mEq/liter*)	S	3.7±0.2(6)	3.5±0.1(6)	3.0±0.2(6)	2.6±0.1(6)	2.8±0.1(6)	3.2±0.2(6)	3.4±0.2(5)	3.1±0.3(4)	3.2±0.3(4)
Chloride	I	295±17(6)	255±15(6)	280±5(6)	273±10(6)	257±8(5)	264±4(4)	291±16(3)	260±11(3)	265±19(3)
(*mEq/liter*)	S	294±6(6)	268±5(6)	278±6(6)	277±15(6)	261±7(6)	262±8(6)	272±14(5)	269±23(4)	263±14(4)
Urea	I	2.5±0.1(6)	2.2±0.1(6)	2.5±0.1(6)	2.3±0.1(6)	2.4±0.1(5)	2.2±0.1(4)	2.4±0.1(3)	2.3±0.1(3)	2.3±0.0(3)
(g %)	S	2.5±0.0(6)	2.2±0.1(6)	2.4±0.0(6)	2.3±0.1(6)	2.3±0.1(6)	2.2±0.1(6)	2.1±0.1(5)	2.3±0.1(4)	2.2±0.1(4)
Calcium	I	7.9±0.3(3)	9.9±0.6(6)	10.1±0.4(6)	9.8±0.2(6)	10.4±0.6(3)	9.0±0.4(4)	9.6±1.1(3)	9.3±0.5(3)	9.8±0.2(3)
(*mEq/liter*)	S	7.5±0.6(5)	9.7±0.5(6)	9.3±0.7(6)	9.2±0.3(6)	9.1±0.3(4)	8.5±0.1(5)	9.1±0.4(4)	10.1±0.4(4)	9.7±0.3(4)
Magnesium	I	1.9±0.2(4)	3.2±0.5(6)	2.9±0.3(6)	2.0±0.2(6)	2.9±0.2(3)	2.4±0.6(4)	1.9±0.2(3)	2.0±0.4(3)	1.6±0.1(3)
(*mEq/liter*)	S	2.0±0.4(5)	3.1±0.7(4)	2.9±0.4(6)	2.1±0.3(6)	2.8±0.2(5)	2.1±0.2(5)	2.2±0.3(5)	2.1±0.2(4)	2.0±0.2(4)

of both groups had risen above their pre-operative values ($P < 0.025$). From the 9th to the 26th day post-operative there was a general tendency for both groups to fall with the interrenalectomized remaining slightly higher than the sham; both groups were still higher than their pre-operative values ($P < 0.05$). By the 44th day post-operative there was a slight rise in plasma calcium and both groups had attained values ca. 27% higher than their pre-operative figures.

The osmolalities of both sham and interrenalectomized animals followed in very close pattern; both fell post-operatively and then after a slow rise decreased until, by the 29th day, they both rose and, by the 44th day, were higher than the pre-operative values ($P < 0.025$) for the sham and $P < 0.01$ for the interrenalectomized).

Chloride, like urea, showed a noticeable drop by the 6th post-operative day in both groups with the interrenalectomized falling slightly lower than the sham. The two then rose again by the 9th day and gradually levelled out, except for the rise by the interrenalectomized at the 29th day. Both groups of animals, however, attained equal values by the 44th day showing only a 10% decrease from their pre-operative figures.

Sodium values rose immediately post-operative in both groups and on the 6th day the sham values were higher ($P < 0.001$) than the pre-operative values but there was no significant change in the interrenalectomized group. From the 6th to the 13th days, Na^+ fell in both groups from the pre-operative levels ($P < 0.001$) and then increased in both groups, from the pre-operative figures ($P < 0.001$) over the next 3 days. This was followed by a decline in sodium in both interrenalectomized and sham animals until by the 44th day they both attained pre-operative values.

Plasma potassium fell in both groups by the 6th day and continued to do so until the 13th day when both sham and interrenalectomized animals were lower than their pre-operative values ($P < 0.001$ for both). Potassium levels then rose in both sham and interrenalectomized animals ($P < 0.025$ for both) between the 13th and 23rd days and continued to rise in the sham until the 30th day but fell in the interrenalectomized group; difference between the two groups was not significant, however ($P > 0.2$). By the 44th day neither group had plasma potassium values significantly different from the respective pre-operative values ($P > 0.1$).

Plasma magnesium levels further emphasized the similar post-operative behavior of the sham and interrenalectomized animals. During the first 5 days post-operative, there was a sharp rise followed by a decline during the 6th–13th days, almost to the original pre-operative values. A sharp rise occurred in both groups over the next 5 days. This was followed by a decline ($P < 0.05$) which brought both groups close to their pre-operative values.

Exploratory Stress Experiments

In early exploratory experiments on reduced salinity, involving 30 fish (29 *R. radiata*; 1 *R. ocellata*) various observations were made towards selection

of appropriate conditions to evaluate interrenalectomy. In 20 and 33% sea water four normal animals died shortly after 48 hr. In 50% sea water a normal *R. ocellata* survived 44 days, and a normal *R. radiata* survived 28 days. Both showed a very gradual decline in plasma urea values, the former falling from 1.9–1.1 g %. Six fish in 60% sea water were equally divided into interrenalectomized, sham-operated, and normal "control" animals. Stress was apparently too great, for, although plasma urea values fell in the interrenalectomized skates and deaths occurred within 7–9 days, the same urea pattern applied to the sham-operated and normal animals. Deaths occurred between 5 and 7 days in the shams whereas the normal fish survived 14–21 days.

In 75% sea water results obtained on 18 skate were more satisfying (Table II) in that the normal animals maintained plasma urea levels. The pre-operative interrenalectomized values were higher in plasma urea than the 7–9 day post-operative figures ($P < 0.005$) and these, in turn, were significantly lower ($P < 0.01$) than normal fish held 7–9 days. However, the 7–9-day values of the interrenalectomized fish were not significantly lower than the 7–9-day values of the sham-operated fish ($P < 0.4$). Neither the pre-operative plasma urea levels of the normal or the sham-operated skate were statistically significant with their post-operative 7–9-day values ($P > 0.4$; $P > 0.1$ respectively); nor were the 7–9-day values significantly different between the two groups ($P > 0.05$).

Exploratory experiments involving stress for 1 hr in fresh water, or sudden temperature change, produced no large difference between the sham and interrenalectomized fish in any of the plasma components (Table III) although there was a suggestion that temperature shock slightly elevated plasma calcium in the interrenalectomized skate compared with the sham or normal skate.

Steroid Concentration After Interrenalectomy

Plasma 1α-hydroxycorticosterone was rapidly depleted in a single *R. radiata* after interrenalectomy, and most of the steroid had disappeared within 24 hr post-operative (Fig. 1).

DISCUSSION

A most interesting point of the investigation is the uniform behavior of the sham-operated and the interrenalectomized animals in all the analyses and, although there are statistically significant pre- and post-operative values, the two groups parallel each other throughout, with the exception of Ca^{++} during the 13th–23rd days. Thus, Hartman's statement that "If the interrenal plays any role in the electrolyte metabolism of the skate, there is no evidence to support it in our observations" (Hartman et al., 1944), was verified with the exception of Ca^{++}. Elevated liver glycogen in shammed animals prompted Hartman to conclude "it is quite possible that the stress of the operation wsa a sufficient stimulus to the interrenals to produce overactivity of the secretory cells (1944)." However, our animals lived sufficiently long that stress to

TABLE II. Plasma urea levels (g %) in *R. radiata*.

Treatment	Sex	Pre-operative value	Time (days post-operative) in 75% sea water								
			1	2	3	4	5	6	7	8	9
Interrenalectomized	♀	1.83	1.73		1.61	1.78			1.47		
	♂	1.84		1.69				1.58	1.66		1.60
	♂	1.81		1.81				1.59	1.57		1.59
	♂	1.69	1.65			1.62			1.53		1.49
	♂	1.79	1.80			1.86			1.82		1.78
	♂	1.85		1.57		1.38			1.46		1.37
	♀	1.85		1.56		1.36			1.17		1.10
Sham-operated	♀	1.87	1.78		1.71	1.57			1.40		
	♂	1.55		1.93				1.90	1.88		1.85
	♀	1.83		1.80				1.73	1.72		1.72
	♂	1.69	1.74						1.67		1.51
	♂	1.69		1.43		1.33			1.23		1.18
	♀	1.71		1.72		1.64			1.72		1.52
Normal	♀	1.80	1.64	1.74			1.64	1.74		1.72	
	♂	1.75		1.79				1.77	1.82		1.84
	♂	1.70	1.70						1.75		1.83
	♂	1.67		1.69		1.73			1.68		Died
	♀	1.64		1.79		1.76			1.71		1.61

TABLE III. Results of freshwater and warm-water stress experiments.

		Sodium (*mEq/liter*)	Potassium (*mEq/liter*)	Chloride (*mEq/liter*)	Urea (g %)	Calcium (*mEq/liter*)	Magnesium (*mEq/liter*)
Freshwater stress							
Interrenalectomized	Pre-operative	300	3.6	286	2.2	7.8	2.2
Sham		297	2.7	293	2.4	7.1	1.9
Interrenalectomized	2 days post-operative and before fresh water	304	2.9	295	2.3	7.8	2.8
Sham		319	3.1	294	2.4	8.3	2.5
Interrenalectomized	After 1 hr in fresh water	281	3.3	281	2.0	7.8	2.7
Sham[a]		293	4.2	267	1.8	7.2	3.6
Warm-water stress							
Interrenalectomized	Pre-operative	312	3.1	303	1.9	9.3	2.8
Sham		297	3.3	290	2.2	9.0	2.6
Interrenalectomized	2 days post-operative before change of 11 C (from 1 to 12 C)	315	3.1	300	1.9	10.0	3.1
Sham		302	3.1	293	2.2	9.8	2.8
Interrenalectomized	After 1 hr in 12 C salt water	312	3.3	310	1.7	10.0	3.4
Sham		306	3.1	295	2.1	9.5	2.7

[a]Had to be killed and bled from the heart.

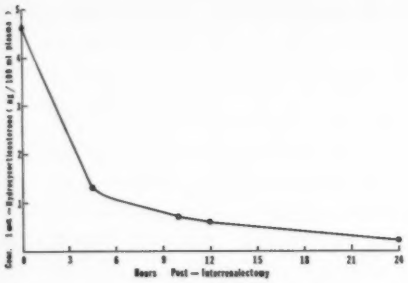


FIG. 1. Plasma levels of 1α-hydroxycorticosterone in a male *R. radiata* after interrenalectomy.

shammed animals might be expected to be overcome at the favorable temperature (8 C) employed. Before the experiment reported in Table I was carried out, a "sham-operation" consisted of disturbing the area around the gland and thus, possibly, disrupting normal blood supply as might occur in an interrenalectomized animal. Since similar plasma electrolyte levels were obtained for shammed and interrenalectomized fish held in sea water, it was decided that for future experiments, a "sham-operation" would consist of cutting only the skin, muscle, and nerves. No damage to the gland occurred and the blood supply remained normal in the area, all with the anticipation that the sham would now differ in its reaction to post-operative "stress" from the interrenalectomized animal. However, both groups reacted post-operatively in a nearly identical manner and it would seem that this skate which outwardly shows few signs of distress, may be upset rather easily.

The duration of survival was very rewarding as over half lived ca. 60 days after the operation. These survival times are much longer than those obtained by earlier investigators mentioned by Hartman (1944). This endurance could be attributed, in whole or in part, to maintaining the animals at the low temperature (8 C) to which this species is accustomed, and their being kept in circulating sea water. Fasting no doubt contributed to changes in various components over the 60-day period but these animals are not very active at this temperature. We did get a slight fall in urea and a small rise in sodium post-operatively, both simulating Hartman's analyses on normal skate (1941). He concluded that because these two tend to reciprocate each other in the individual, it supported the idea that urea played a part in osmotic regulation (Smith, 1936).

Hartman had found that after interrenalectomy, plasma Na^+, Mg^{++}, and Cl^- rose, and urea fell (1944). However, he established earlier in normal fish fasting for 7 days an increase in the same three (Na^+, Mg^{++}, and Cl^-) and a decrease in urea (1941), thus showing the similar effects caused by starvation and interrenalectomy.

Our animals were both interrenalectomized and fasting and our findings somewhat agree with Hartman et al. (1941) with the exception that Cl^- values were lowered, as observed in muscle chloride for interrenalectomized *Anguilla*

rostrata (Butler and Langford, 1967). Magnesium rose immediately post-operatively then fell to ca. pre-operative values by the 13th day, and calcium rose statistically significantly in the interrenalectomized animals between the 13th and 23rd days. Potassium values were quite different from those of Hartman et al., being more consistent and very noticeably lower. This could be a species difference, although in five species of *Raja*, Smith (1929) reports a plasma range for K^+ of only 4.5–6.8 mM per liter. Our sampling was done from the caudal vein with no resulting hemolysis in any of the samples. Hartman (1941) sampled from the heart and caudal vein and found that skates' blood hemolyses very readily, although he states that hemolysed samples were discarded. In preliminary studies we found that there was frequently a very significant difference in K^+ in samples taken from the heart as compared with those taken from the tail. It is also of note that the majority of heart samples did hemolyse whereas rarely did this problem exist in caudal vein plasma. Hemolysis does cause a definite increase in K^+ values since exploratory studies established that K^+ conc. in whole blood was 12.6–18.2 mEq/liter higher than its plasma. Idler and Truscott (1967) observed that when a radioactive steroid was injected into the heart there was leakage into the pericardial fluid. There is a distinct possibility that "heart" samples taken by us and by Hartman et al. (1944) may have contained pericardial fluid. Pericardial fluid contains ca. 8–20 mM per liter K^+ (Smith, 1929) which is much higher than plasma K^+.

It has been shown by Middler et al. (1968) that tricaine methane sulphonate causes a loss in body water in the frog, resulting, therefore, in an increase of plasma Na^+ in the 72 hr post-operative; normal balance returns after 2–3 days. We, too, used tricaine methane sulphonate prior to interrenalectomy and found that there was a rise in plasma Na^+ by the 6th day post-operative, which remained at a high level until the 13th day. However, it should be noted that (1) Hartman et al. (1944) obtained an increase post-operatively in sham and interrenalectomized fish in which no mention was made of an anaesthetic; and (2) he indicates that Na^+ increased in normal animals after 7 days fasting (1941). We were a little surprised that interrenalectomy did not have a greater effect on plasma Na^+ levels in view of the demonstrated biological activity of 1α-hydroxycorticosterone for a rodent (Idler et al., 1967) and in the toad bladder Na^+ transport bio-assay (unpublished data).

In post-mortem examination of animals which died during the experiment, it was noticed that there was deterioration locally in the former gland area, but the kidney itself remained healthy in appearance. In the interrenalectomized animals that were killed after the 60-day period, however, severe kidney damage was evident. It is known that warm-blooded animals frequently die 10–15 days after complete removal of the adrenal glands, and that during this time, there is a rise in Ca^{++}. Canas et al. (1966) states that interrenalectomized rats showed no effect on Ca at^{++} 24 hr. However, when nephrectomy and interrenalectomy were both performed, there was an increase in

Ca^{++}. Thus, it is possible that kidney damage contributed to the rise in Ca^{++} obtained in our investigation but this is not likely since the damage was greater towards the end of the experiment whereas the greatest effect on plasma calcium was at an earlier stage.

Stress Experiments

In 75% sea water, it appears that the interrenalectomized fish are stressed to a greater degree than are the sham-operated and normal animals, particularly the latter, as the plasma urea levels were significantly lower in the interrenalectomized as compared with the normal fish.

The lower salinities eventually caused death, which occurred faster in the operated fish than in the normal animals. Unoperated fish stressed in 50% sea water lived up to 44 days, although urea fell continually, never reaching stability, which, of course, may have been due to inanition (Hartman et al., 1941).

It is reasonable to assume that an interrenalectomized animal should respond to stress to a greater degree than a sham-operated or normal animal. It appears that reduced salinity of 20–25% may be near the limit that could be used to differentiate between operated and normal animals because the normal animals are affected when salinities are reduced much further.

Although no statistical differences were obtained between the interrenal and sham-operated animals stressed in fresh water or by temperature change for 1 hr, it is interesting to note that only one fish died (two lived in later experiments involving stress for 1 hr in fresh water); all others recovered, two still living after 40 days. In 1930, Chaisson reported 100% mortality in fish subjected to fresh water for 50 min or more, soon after they had been returned to sea water. We also noted that the fish turned a very pale grey color under freshwater stress, a change comparable with that observed after prolonged interrenal insufficiency. However, normal color returned after a few hours in salt water.

It should be noted that, in contrast to mammals, cortical but not medullary tissue is removed by interrenalectomy of elasmobranchs.

The only study on elasmobranchs which has attempted to show effects of a corticoid on electrolyte balance is that of Chan et al. (1967) after in vivo injections in the lip-shark. They found that deoxycorticosterone and cortisol caused an increase in muscle K^+ and also that a cortisol injection, alone, or coupled with hypertonic saline loading resulted in a rise of Na^+ concentration of rectal gland tissue but lowered the Na^+ concentration in the rectal gland fluid. It is not known what blood cortisol levels were attained in the lip-shark studies. An effect of cortisol on an intact interrenal could be synergistic with the normal adrenal steroids, or may suppress normal steroidogenesis. Recent studies (Idler and Truscott, 1967; Truscott and Idler, 1968) have established 1α-hydroxycorticosterone, rather than cortisol, to be the major steroid of several elasmobranchs. Production rates and blood levels of 1α-hydroxycorticosterone in elasmobranchs have been reported, and, if an effect of

interrenalectomy can be demonstrated, then available data should facilitate study of this steroid at physiological concentration. Unfortunately 1α-hydroxycorticosterone is not yet available in quantity and it is thus necessary to continue to demonstrate the effect of interrenalectomy on small animals or in vitro systems which require relatively small quantities of steroid.

ACKNOWLEDGMENTS

Thanks are expressed to Mrs Mary Jane O'Halloran for assistance with some of the analyses. Several discussions with Miss Beryl Truscott are gratefully acknowledged.

REFERENCES

BUTLER, D. G., AND R. W. LANGFORD. 1967. Tissue electrolyte composition of the freshwater eel (*Anguilla rostrata*) following partial surgical adrenalectomy. Comp. Biochem. Physiol., **22**: 309–312.

CANAS, F. M., W. H. BERGSTROM, AND S. J. CHURGIN. 1967. Effects of the adrenal on calcium homeostasis in the rat. Metabolism, **16**(7): 670–674.

CHAISSON, A. F. 1930. The changes in the blood concentration of *Raja erinacea* produced by modification of the salinity of the external medium. Contrib. Canadian Biol. Fish., **5**: 477–484.

CHAN, D. K. O., J. G. PHILLIPS, AND I. CHESTER JONES. 1967. Studies on electrolyte changes in the lip-shark, *Hemiscyllium plagiosum* (Bennett) with special reference to hormonal influence on the rectal gland. Comp. Biochem. Physiol., **23**: 185–198.

CHESTER JONES, I. 1957. The adrenal cortex. Cambridge University Press, Cambridge. p. 129–130.

CHESTER JONES, I., AND J. G. PHILLIPS. 1960. Adrenocorticosteroids in fish. Symp. Zool. Soc. London, I: 17–32.

HARTMAN, F. A., L. A. LEURI, K. A. BROWNELL, C. A. ANGERER, AND F. F. SHELDEN. 1944. Effect of interrenalectomy on some blood constituents in the skate. Physiol. Zool., **17**: 228–238.

HARTMAN, F. A., L. A. LEURI, K. A. BROWNELL, F. F. SHELDEN, AND R. F. WALTHER. 1941. Some blood constituents of the normal skate. Ibid., **14**: 476–486.

IDLER, D. R., H. C. FREEMAN, AND B. TRUSCOTT. 1967. Biological activity and protein binding of 1α-hydroxycorticosterone: an interrenal steroid in elasmobranch fish. Gen. Comp. Endocrinol., **9**: 207–213.

IDLER, D. R., AND B. TRUSCOTT. 1967. 1α-hydroxycorticosterone. Synthesis *in vitro* and properties of an interrenal steroid in the blood of cartilaginous fish (Genus *Raja*). Steroids, **9**: 457–477.

KLEIN, B. 1958. Chloride. Std. Methods Clin. Chem., **11**: 22–25.

MIDDLER, S. A., C. R. KLEEMAN, AND E. EDWARDS. 1968. Influence of tricaine methane sulphonate anaesthesia on fluid and salt metabolism of the toad, *Bufo marinus*. Comp. Biochem. Physiol., **24**: 1065–1067.

QUINN, P. J., I. G. WHITE, AND B. R. WIRRICK. 1965. Studies of the distribution of the major cations in semen and male accessory secretions. J. Reprod. Fertility, **10**: 379–388.

SMITH, H. W. 1929. The composition of the body fluids of elasmobranchs. J. Biol. Chem., **81**: 407–419.

1936. The retention and physiological role of urea in elasmobranchii. Biol. Rev., **11**: 4–82.

TRUSCOTT, B., AND D. R. IDLER. 1968. The widespread occurrence of a corticosteroid 1α-hydroxylase in the interrenal of elasmobranchii. J. Endocrinol., **40**: 515–526.

VAN SLYKE, D. D., AND G. E. CULLEN. 1954. Determination of urea. *In* P. B. Hawk, B. L. Oser, W. H. Summerson [ed.] Practical physiological chemistry. 13th ed. Blakiston Company, Inc., Toronto, Ont. p. 551–553.

Fish Otoliths in Cetacean Stomachs and Their Importance in Interpreting Feeding Habits[1]

By John E. Fitch

California State Fisheries Laboratory
Terminal Island, Calif., USA

AND

Robert L. Brownell, Jr.

Los Angeles County Museum of Natural History
Los Angeles, California, USA

ABSTRACT

The stomachs of 17 cetaceans of seven species (3 *Kogia simus*, 5 *Stenella longirostris*, 3 *S. graffmani*, 2 *Lagenorhynchus obliquidens*, 2 *Delphinus delphis*, 1 *Lissodelphis borealis*, and 1 *Phocoena sinus*) yielded 18,164 fish otoliths representing over 51 species, 40 genera, and 22 families. Lanternfish (family Myctophidae) otoliths accounted for more than 89% of the total, and they had come from at least 19 species belonging to nine genera. Only two fish species could have been identified if we had not been able to utilize otoliths. To be useful in food studies involving otoliths, cetacean stomachs cannot be placed in formalin solutions, even for short periods.

The kinds and diversity of species preyed upon by several of these cetaceans indicate that they routinely forage in depths of 650–800 ft (200–250 m), and a few such as *Kogia simus* may descend to 1000 ft (300 m) or deeper.

INTRODUCTION

Although many references are available concerning the few entire fishes encountered in cetacean stomachs, or observed being fed upon, no publication presents a thorough or extensive discussion of the piscivorous activities of whales, porpoises, and dolphins. This paucity of information apparently reflects the failure of cetacean researchers to recognize fish otoliths per se, and to realize the usefulness of these objects in food habit studies. Scales, vertebrae, eye lenses, teeth, bits of smelly flesh, and other fish fragmentia making up the soupy, often worm-ridden mixture typically encountered in a cetacean stomach seldom can be identified to species, but teleost otoliths are slow to digest and can furnish accurate qualitative as well as quantitative data. Their ultimate identification, however, requires a fairly extensive comparative collection from the species most likely to be fed upon.

During the past several years, we have routinely examined stomachs of cetaceans that have been stranded, harpooned, or captured incidental to purse-seine and gillnet fisheries, and have saved otoliths, cephalopod beaks,

[1]Received for publication May 31, 1968.

J. Fish. Res. Bd. Canada, 25(12): 2561–2574, 1968.
Printed in Canada.

and other identifiable remains that we have encountered. The stomachs of seven species (pygmy sperm whale, *Kogia simus*, Pacific spotted dolphin, *Stenella graffmani*, spinner dolphin, *Stenella longirostris*, white-sided dolphin, *Lagenorhynchus obliquidens*, common dolphin, *Delphinus delphis*, northern right whale dolphin, *Lissodelphis borealis*, and Gulf of California harbor porpoise, *Phocoena sinus*) have yielded otoliths, and all but *Phocoena sinus* have also contained cephalopod beaks. Although each individual bony fish has three pairs of otoliths (sagittae, asterisci, and lapilli), the asterisci and lapilli usually are extremely small, and even if found, they rarely are used in food studies involving fish ear stones. All otoliths referred to in this report are sagittae unless otherwise noted.

Because formalin will dissolve fish otoliths and render them unrecognizable in a matter of days, stomachs should be examined as soon as possible, or they should be frozen until they can be worked on. Preservation of stomachs in alcohol is satisfactory for a short period, but subsequent separation of otoliths and other identifiable remains is much more difficult and time consuming than when working with fresh material. Otoliths can be preserved dry or in alcohol, but first they should be rinsed in water to remove extraneous amorphic material. When making comparisons, a binocular microscope at 6–10 magnifications is almost a necessity.

Although otoliths are the most important tools available for identifying teleost fishes eaten by whales, porpoises, and dolphins, only 12 reports have noted their occurrence in cetacean stomachs since the first was published in 1903.

Thomas Scott (1903) opened the door more than 65 years ago for researchers to use teleost otoliths in determining food habits of fish-eating cetaceans. He identified and illustrated 280 gadid (Gadidae), sand lance (*Ammodytes* sp.), and other earstones found in the stomach of a common porpoise, *Phocoena phocoena*, captured off the coast of Scotland. In spite of Scott's pioneer work, we know of only 12 additional published reports of otolith occurrence in cetacean digestive tracts, and 20 years were to pass before the first of these appeared (Schmidt, 1923). In that year, Johannes Schmidt, in a letter to the editor of *Nature*, reported having sent to the British Museum of Natural History 15,191 sagittae that he had removed from the stomach of a "common long-nosed porpoise," *Delphinus delphis*, harpooned off southern Spain in the Mediterranean during a research cruise on the *Thor* in June 1910. G. A. Frost (1924), after seeing Schmidt's note, examined 4338 of these otoliths and assigned them to six species in three families (4324 Myctophidae, 10 Macrouridae, and 4 Scomberesocidae). His outline drawings are crude, but there is no question that he correctly identified to family the four kinds of lanternfishes and possibly the scomberesocid, but his "*Macrurus*" very likely is a barracudina, family Paralepididae.

Vladykov (1946) was the next to note fish otoliths in cetacean stomachs, reporting more than 1000 cod (*Gadus* and *Microgadus*), smelt (*Mallotus*), and other sagittae from the digestive tracts of white whales, *Delphinapterus*

leucas, taken in the Saint Lawrence River, Canada. In 1948, Scheffer and Slipp noted "otoliths and bones of fish" in the stomach of a pygmy sperm whale, *Kogia breviceps*, from the coast of Washington. They questionably identified a partially digested fish as *Trichodon*, but were unable to assign names to the 21 otoliths, none of which appears to have been saved (V. B. Scheffer, personal communication).

The remaining eight reports we were able to find that mentioned otoliths in cetacean stomachs have been published during the last 12 years. Three of these (Cadenat, 1959a, b; and Cadenat and Doutre, 1959) concern *Tursiops truncatus*, *Delphinus delphis*, and *Stenella longirostris* from off the west coast of Africa, whereas the other five publications (Brown and Norris, 1956; Norris and Prescott, 1961; Best, 1963; Daugherty, 1965; and Fiscus and Niggol, 1965) pertain to dolphins from the eastern north Pacific, primarily off California.

The African *Tursiops* stomach (Cadenat, 1959a) contained several partially digested snake mackerel, *Gempylus serpens*, and numerous otoliths from at least four kinds of deep-living macrourids and morids (Moridae), but the earstones noted in the stomachs of 10 of 25 *D. delphis* (Cadenat, 1959b) and 4 of 4 *S. longirostris* (Cadenat and Doutre, 1959) were neither enumerated nor identified, except for the notation that a large percentage of the otoliths in the *Stenella* stomachs appeared to be "*a la famille des Scopelidae*" [= Myctophidae].

The large, pointed, first stomach chamber of a *Lagenorhynchus obliquidens* from off California was "filled with partially digested anchovies, fish bones, otoliths, fish eye lenses and one blanched but otherwise undigested squid..." (Brown and Norris, 1956). Neither these otoliths nor the "unidentified fish otoliths" noted in the stomach of a *Delphinus delphis* (Fiscus and Niggol, 1965) are available for examination. A *Tursiops gilli* from southern California had eaten mostly shallow-water bottom-living forms as evidenced by 102 otoliths from 8 species (Norris and Prescott, 1961). On the other hand, the stomach of a *Phocoenoides dalli* reported by these same authors yielded 30 otoliths from two species (hake, *Merluccius productus*, and anchovies, *Engraulis mordax*) that it very likely had consumed more than 400 ft (120 m) beneath the surface. Finally, Best (1963) in discussing *Merluccius productus*, stated that "hake otoliths have been identified among the stomach contents of... *Lagenorhynchus obliquidens* and *Phocoenoides dalli*," and Daugherty (1965) reported that otoliths often are found in stomachs of eastern Pacific cetaceans mentioning particularly *Stenella*, *Tursiops*, *Lagenorhynchus*, and *Phocoenoides*.

FISHES EATEN BY *KOGIA SIMUS*

Brownell examined the stomachs of three pygmy sperm whales harpooned offshore from Taiji, Wakayama, Japan in July 1967, and found 153 otoliths that had come from a minimum of 92 fish representing 18 species in seven families (Table I, Fig. 1). Unfortunately we lack a good comparative collection of otoliths from Japanese fishes so we cannot identify many of these sagittae

TABLE I. Numbers and kinds of fish otoliths found in stomachs of three *Kogia simus* captured off Taiji, Japan, during July 1967.

Kind of fishes eaten	Whale identity and no. of otoliths		
	RLB 392[a]	RLB 397[a]	RLB 400[a]
Argentinidae			
Glossanodon sp.	3	5	2
Nansenia sp.		2	2
Congridae			
Congrid		2	
Gonostomatidae			
Gonostomatid			3
Ichthyococcus sp.	10		7
Macrouridae			
Coelorhynchus?			4
Macrourid #1	3	1	7
Macrourid #2		14	9
Moridae			
Morid #1	3	14	
Morid #2		1	
Morid #3		3	
Myctophidae			
Diaphus #1			1
Diaphus #2			2
Hygophum?			1
Lampadena #1	19	12	14
Lampadena #2			2
Symbolophorus sp.		1	3
Sternoptychidae			
Polyipnus sp.		2	1
Total	38	57	58

[a]R. L. Brownwell field numbers.

to genus and species. Cephalopod beaks and crustacean remains also were present in these stomachs.

The 38 otoliths (5 species) found in one stomach (RLB 392) were from at least 22 fish (10 *Lampadena*, 5 *Ichthyococcus*, 3 morids, 2 *Glossanodon*, and 2 macrourids), whereas the 57 and 58 otoliths in the other two stomachs represented a minimum of 37 (11 species) and 33 fish (14 species), respectively. Only 3 of the 18 species (*Lampadena*, *Glossanodon*, and a macrourid) had been eaten by all three *Kogia*, but these three species contributed 66 of the 153 otoliths. Most of the otoliths were in relatively good condition, but even those considerably eroded from digestive action were readily identified. A family-by-family discussion of the 153 otoliths in these three stomachs (Table I) follows.

Argentinidae. — Fourteen of the 153 otoliths were from two genera of argentines, *Glossanodon* and *Nansenia*, representing a minimum of eight fish. All of these otoliths were from large adults, but *Glossanodon* probably never exceeds 10 inches (250 mm) and 2 oz (60 g), whereas *Nansenia* is slightly smaller. Members of these two genera seldom approach within 650 ft (200 m) of the surface.

Congridae. — A pair of sagittae very similar to those of *Ariosoma* were found in one stomach. Congrids such as *Ariosoma* often inhabit the scattering layer and probably migrate toward the surface at night, possibly even reaching the surface. Although these sagittae were from an adult eel, it probably would have been only 10–12 inches (250–300 mm) long.

Gonostomatidae. — The 20 gonostomatid otoliths we found in these stomachs were from a minimum of 11 fish: 9 *Ichthyococcus*, and 2 unknown gonostomatids, possibly a close relative of *Vinciguerria*. Although all were from large adults, the unknown gonostomatids probably were less than 2 inches (50 mm) long, but several of the *Ichthyococcus* sagittae had come from very large individuals, probably exceeding 5 inches (125 mm). Gonostomatids usually are deeper than 1000 ft (300 m) during daylight hours, but move closer to the surface at night. *Vinciguerria* often reaches the surface at night, but *Ichthyococcus* usually remains 650–800 ft (200–250 m) down.

Macrouridae. — Macrourids usually inhabit muddy bottom areas at depths of 1500–5000 ft (450–1500 m), but some may be found as shallow as 650 ft (200 m) and others deeper than 10,000 (3000 m). Most species never leave the bottom except to move a few feet off during feeding activities. The 38 macrourid otoliths were from three species, and represented at least 22 individuals. All three *Kogia* had fed on these bottom-dwelling forms. Our use of the name *Coelorhynchus* for four of the macrourid otoliths is questionable because of the state of digestion. Most of the macrourid otoliths probably came from 10–14-inch (250–350 mm) long fish weighing as much as $\frac{1}{4}$–$\frac{1}{2}$ lb (100–225 g) each.

Moridae. — The 21 morid otoliths from at least 16 individuals also represented three species of bottom-dwelling fish. These likely were captured at depths exceeding 650 ft (200 m) but shallower than 1500 (450 m). They probably were slightly smaller than the macrourids.

Myctophidae. — Lanternfish otoliths comprised the greatest number (55) and kinds (6) found in these stomachs, but only one kind (45 sagittae from an undescribed species of *Lampadena*) was of major importance. These 45 otoliths represented a minimum of 25 lanternfish, and their sizes suggested that they had come from individuals that were 8–10 inches (200–250 mm) long. Differences between these otoliths and those of the known species of *Lampadena* were pointed out by Nafpaktitis and Paxton (1968) in a recent review of the genus. The other 10 lanternfish otoliths represented five species apparently belonging to four genera (Table I, Fig. 1). All but one of these were in the same stomach. During daylight hours members of these four genera

(*Lampadena*, *Symbolophorus*, *Diaphus*, and *Hygophum*) are found at a depth of about 1000 ft (300 m), but at night all are known to migrate into surface waters. A 4-inch (100-mm) fish would be large for an adult of most of these.

Sternoptychidae. — Three *Polyipnus* otoliths were the only representatives of this family found in these stomachs. *Polyipnus* seldom exceeds 2 inches (50 mm) when full grown, and usually remains 650–800 ft (200–250 m) beneath the surface.

FISHES EATEN BY *STENELLA GRAFFMANI* AND *S. LONGIROSTRIS*

Stenella longirostris and *S. graffmani* occur sympatrically in the eastern tropical Pacific, and frequently school together, often in the company of yellowfin tuna, *Thunnus albacares*. During 1967 and 1968, we found otoliths in the stomachs of five *S. longirostris* and one *S. graffmani* that had been netted with tuna during daylight hours in the eastern Pacific between about 12° and 20°N lat. Previous to 1967, Fitch had identified several thousand otoliths from the stomachs of two *S. graffmani* netted in the same general area during 1959 and 1963 (Table II, Fig. 2). The stomachs of these eight dolphins also contained cephalopod beaks, so there is a slight possibility that some of the otoliths had been transferred from the squid and/or octopus stomachs, particularly those of such tiny fishes as *Vinciguerria*, *Diogenichthys*, and *Bregmaceros*.

Although the five *S. longirostris* had fed upon 6–15 kinds of fish, two kinds of myctophids, *Benthosema panamense* and *Lampanyctus parvicauda*, comprised over 50% of their piscivorous diet, both individually and as a group. *Benthosema panamense* was also important to *S. graffmani*, being the only species noted in one of the three stomachs and contributing all but 3 of the 1238 otoliths found in a second. This tropical lanternfish normally undertakes a diurnal migration, but sometimes dense "balls" (schools) of *Benthosema* remain at the surface during daylight hours, where they have been observed under attack by birds, fish, and dolphins. Even though both dolphins had fed heavily upon *Benthosema*, we believe that *S. longirostris* had captured its prey several hundred feet down, whereas *S. graffmani* had fed at or near the surface.

A family-by-family discussion of the several thousand otoliths found in *Stenella* stomachs (Table II) follows.

Bathylagidae. — The *Bathylagus* otoliths in the stomachs of *Stenella longirostris* may have been those of *B. pacificus*, a species that lives more than 650 ft (200 m) beneath the surface and does not undertake a diurnal migration. They were not from *B. stilbius*, one of the commonest blacksmelt in that area and a known vertical migrator. None of the 15 otoliths in the three stomachs was from a large fish, perhaps 4 or 5 inches (100–125 mm) being about maximum.

Bregmacerotidae. — Only the stomachs of *S. longirostris* contained otoliths of *Bregmaceros bathymaster*, even though the species is known to migrate from

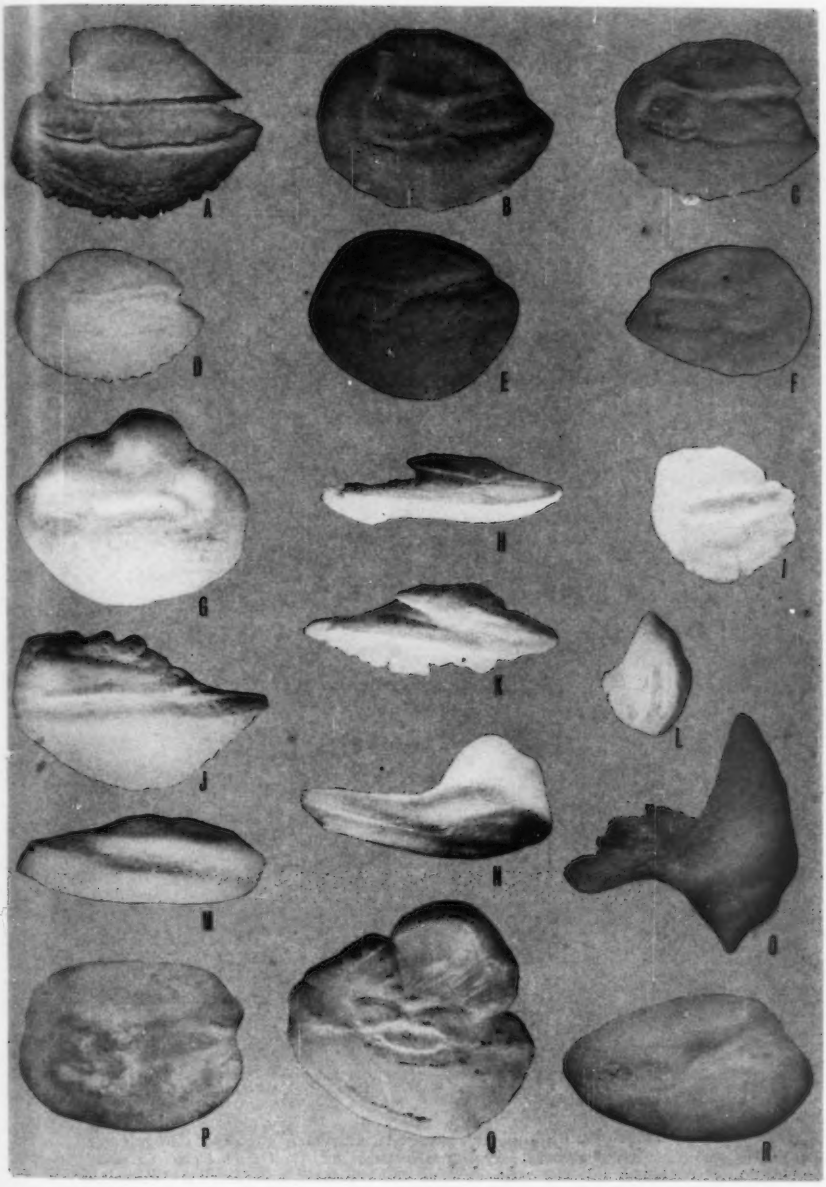


FIG. 1. Sagittae (inner faces) of 18 species of fish found in stomachs of *Kogia simus*. For each illustrated otolith, information on whether it is left (*l*) or right (*r*), length (mm), and notations, if it is atypical are: (A) *Lampadena* #1, *l*, 9.2; (B) *Symbolophorus* sp., *l*, 4.2; (C) *Diaphus* #1, *l*, 2.6; (D) *Lampadena* #2, *l*, 3.2; (E) *Hygophum* ?, *l*, 2.7, badly digested; (F) Diaphus #2, *r*, 2.4, badly digested; (G) congrid, *r*, 5.6; (H) morid #1, *r*, 7.3; (I) gonostomatid, *l*, 1.0; (J) *Glossanodon* sp., *l*, 7.4; (K) morid #2, *r*, 6.7; (L) *Polyipnus* sp., *r*, 1.8, rostrum missing; (M) *Nansenia* sp., *r*, 5.2, badly digested, rostrum tip missing; (N) morid #3, *r*, 7.2, badly digested; (O) *Ichthyococcus* sp., *r*, 5.7; (P) macrourid #1, *l*, 4.0; (Q) macrourid #2, *l*, 5.0; (R) *Coelorhynchus* ?, *l*, 4.5, badly digested.

Fitch and Brownell — J. Fish. Res. Bd. Canada

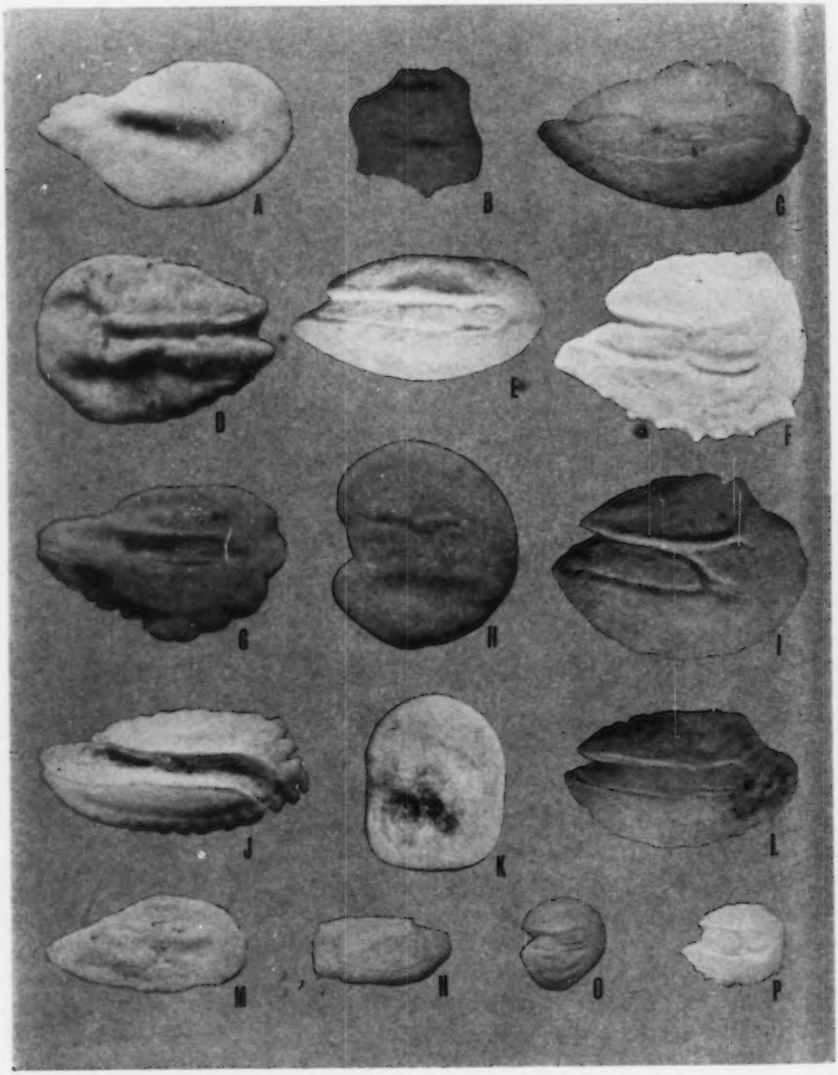


FIG. 2. Sagittae (all inner faces except *Benthalbella*) of 16 species of fish found in stomachs of *Stenella longirostris* and *S. graffmani*. For each illustrated otolith, information on whether it is left (*l*) or right (*r*), length (mm), and notations if it is atypical are: (A) *Bathylagus* sp., *r*, 1.7, rostrum tip missing; (B) *Bregmaceros bathymaster*, *l*, 1.5; (C) *Oxyporhamphus micropterus*, *r*, 5.4; (D) gonostomatid, *l*, 1.4; (E) *Lampanyctus parvicauda*, *r*, 4.1; (F) *Diaphus* sp., *r*, 3.0; (G) *Vinciguerria lucetia*, *r*, 1.5; (H) *Diogenichthys laternatum*, *r*, 1.1; (I) *Symbolophorus evermanni*, *r*, 4.1; (J) centrolophid ?, *r*, 4.6; (K) *Lampanyctus idostigma*, *r*, 0.9; (L) *Myctophum aurolaternatum*, *r*, 4.0; (M) unidentified from *S. longirostris* M-33-67, *r*, 2.4; (N) *Benthalbella* sp., *r*, 2.6, outer face; (O) *Hygophum* sp., *r*, 1.7; (P) *Benthosema panamense*, *r*, 2.0.

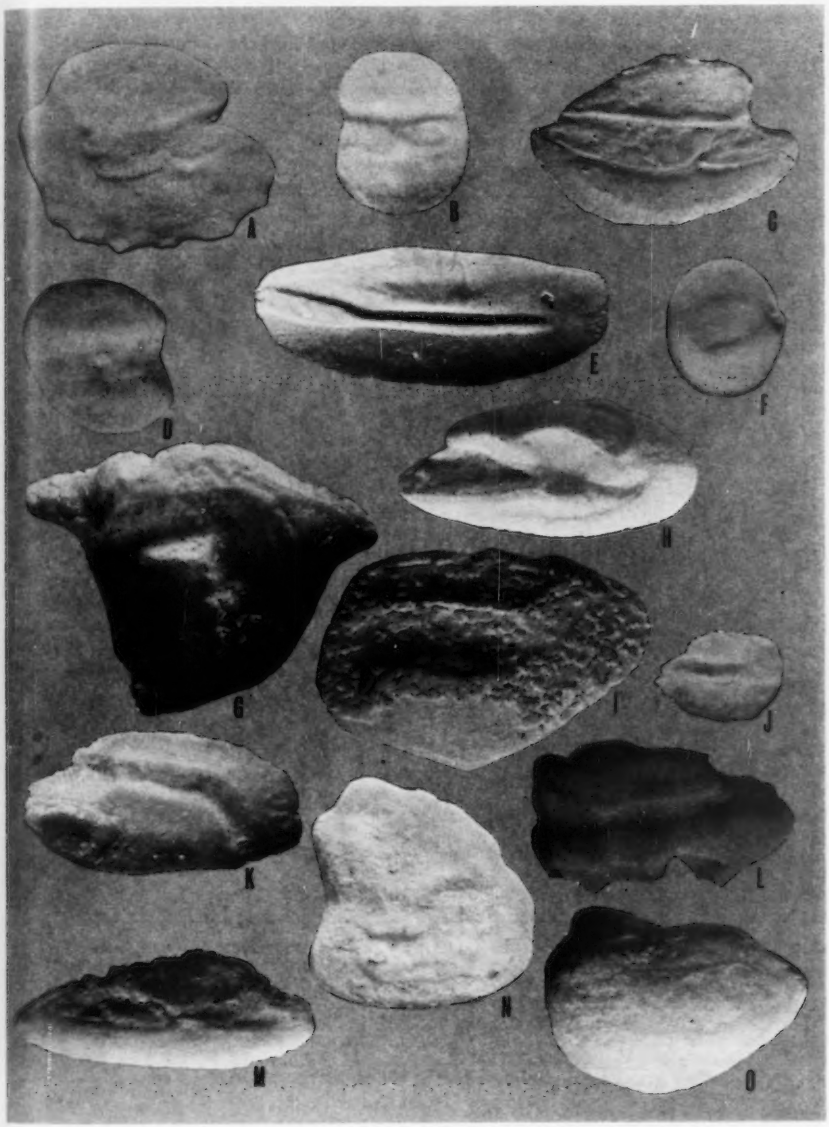


FIG. 3. Sagittae (inner faces) of 15 species of fish found in stomachs of *Lissodelphis borealis* (A through F), *Phocoena sinus* (G and K), *Lagenorhynchus obliquidens* (H and I), and *Delphinus delphis* (J, I, M, and O). For each illustrated otolith, information on whether it is left (*l*) or right (*r*), length (mm), and notations if it is atypical are: (A) *Diaphus* sp. near *theta*, *l*, 2.1; (B) *Lampanyctus* sp. near *ritteri*, *r*, 1.1; (C) *Lampadena urophaos*, *r*, 6.4; (D) *Triphoturus mexicanus*, *l*, 1.3, badly digested; (E) *Icichthys lockingtoni*, *r*, 9.1; (F) *Scopelogadus bispinosus*, *l*, 1.0; (G) *Bairdiella icistius*, *r*, 8.7; (H) *Engraulis mordax*, *r*, 3.5, badly digested; (I) *Seriphus politus*, *l*, 7.5, lumpy from formalin preservation; (J) *Bathylagus* sp., *r*, 1.1, rostrum tip missing; (K) *Orthopristis reddingi*, *r*, 6.7; (L) *Argentina sialis*, *l*, 2.7, ventral margin broken; (M) *Merluccius productus*, *l*, 7.2; (N) *Porichthys notatus*, *r*, 2.9; (O) *Otophidium taylori*, *r*, 4.4.

TABLE II. Numbers and kinds of fish otoliths found in the stomachs of two species of *Stenella* from the eastern tropical Pacific.[a]

	No. of otoliths							
	Stenella longirostris					*Stenella graffmani*		
Kinds of fishes eaten	1	2	3	4	5	1	2	3
Bathylagidae								
Bathylagus sp.	1	12			2			
Bregmacerotidae								
Bregmaceros bathymaster	11	76	6	89	61			
Centrolophidae?								
Centrolophid?	2	16			5	45		
Exocoetidae								
Oxyporhamphus micropterus						29		
Gonostomatidae								
Gonostomatid		7						
Vinciguerria lucetia	256	126	3	435	497		3	
Myctophidae								
Benthosema panamense	1	241	234	6147	983	4	1235	2357
Diaphus sp.	1							
Diogenichthys laternatus	949	97	60	302	15	4		
Hygophum sp.	1	35		4	1			
Lampanyctus idostigma	13	1			12			
Lampanyctus parvicauda	1916	465	30	27	282			
Myctophum aurolaternatum	2	107		7	106	8		
Symbolophorus evermanni	3	13						
Unidentifiable myctophids	78	54	13					
Paralepididae								
Stemonosudis?					30			
Scopelarchidae								
Benthalbella sp.		1						
Unidentified		2			1	1		
Total	3234	1253	346	7011	1995	91	1238	2357

[a]Capture data (all specimens netted with tuna; M-numbers are accession numbers of Cetacean Research Laboratory, Little Company of Mary Hospital, Torrance, Calif.). *Stenella longirostris*: (1) M-57-66, about 350 miles (>550 km) SW of Manzanillo, Mex., in early 1966; (2) M-33-67, same general area as (1), but March 1967; (3) M-20-68, 12°N lat, 92°W long, February 21, 1968; (4) M-60-68, 13°N lat, 99°22′W long, April 16, 1968; (5) M-70-68, ca. 350 miles (±550 km) SW of Acapulco, Mex., April 1968. *Stenella graffmani*: (1) M-32-67, ca. 350 miles (>550 km) SW of Manzanillo, Mex., March 1967; (2) 150 miles off Acapulco, Mex., November 1959; (3) off Costa Rica, January 1963, Jules Crane data.

the depths into surface waters at night. A full-grown *B. bathymaster* would hardly exceed 3 inches (75 mm) and 1 g.

Centrolophidae? — The most abundant otoliths in the stomach of *S. graffmani* M-32-67 were those of an unknown stromateoid. These otoliths (Fig. 2J) compare favorably with those of *Seriolella*, but according to Haedrich (1967), *Seriolella* "is restricted to cool temperate waters of the Southern

Hemisphere." We believe that they represent a species of centrolophid, but to our knowledge no member of the Centrolophidae is known from waters off tropical west Mexico. In any event, stromateoids (including Centrolophidae) are noted for their association as juveniles with floating debris, jellyfishes, and similar items, so the fishes these came from probably were eaten at or near the surface. Three of the *S. longirostris* stomachs we examined also contained otoliths of these stromateoids, but in much smaller numbers (Table II).

Exocoetidae. — Twenty-nine otoliths in the stomach of *S. graffmani* M-32-67 were from the shortwing flyingfish, *Oxyporhamphus micropterus*. This tropical species is strictly an inhabitant of surface waters. A really large individual might attain a length of 8 inches (200 mm) and a weight of 2 ounces (55 g).

Gonostomatidae. — Otoliths of *Vinciguerria lucetia* were relatively abundant in four of the five stomachs of *Stenella longirostris*, but only three were present in the *S. graffmani* stomachs. *Vinciguerria lucetia* inhabits depths of 650 to 1000 ft (200–300 m) during daytime, but migrates toward the surface at night and often can be dipnetted from under a bright light suspended above the surface. At maximum size they are just over 2 inches (50 mm) long and weigh but a few grams. Seven otoliths in one *S. longirostris* stomach (M-33-67, Fig. 2D) appear to be those of a gonostomatid but our comparative collection of gonostomatid otoliths was small, so we were unable to make a positive identification.

Myctophidae. — At least eight species of lanternfish had been fed upon by *S. longirostris* and three by *S. graffmani*. Six of these, *Symbolophorus evermanni*, *Myctophum aurolaternatum*, *Diogenichthys laternatus*, *Benthosema panamense*, *Diaphus*, and *Hygophum*, are found in surface waters at night, but the two species of *Lampanyctus* identified from the *S. longirostris* stomachs are deep (±400 m) during daylight hours and usually remain fairly deep (±200 m) at night. Three to 5 inches (75–125 mm) would be about maximum length for all of the myctophids except *Diogenichthys*, which seldom attains 2 inches when full grown.

Paralepididae. — The 30 barracudina otoliths in the stomach of *S. longirostris* M-71-68 are difficult to assign to a genus because of a shortage of comparative material. They are not from *Paralepis*, *Notolepis*, *Sudis*, or *Lestidium*, and several other genera are unknown in the eastern Pacific. Barracudinas are most abundant at depths of 1000–2500 ft (300–800 m), but range both above and below these depths. Adults of *Stemonosudis* are unknown in collections, but the otoliths in this dolphin stomach unquestionably were from adults. Based upon otoliths from other family members, these fish could have been 10–12 inches long (25–30 mm).

Scopelarchidae. — One otolith (from *S. longirostris*) was from a 4- to 5-inch (100–125 mm) *Benthalbella*, a fish that usually lives 800–1000 ft (250–300 m) down during daylight hours. Young individuals migrate into surface waters at night, but the habits of adults are unknown.

FISHES EATEN BY *LAGENORHYNCHUS OBLIQUIDENS*

We examined the stomachs of only two *L. obliquidens* that contained otoliths. One, a 5-ft 11-inch (179.5-cm) long female weighing 121 lb (55 kg), was found stranded at Long Beach, California, on August 21, 1967. Its stomach was gorged with partially digested fish (Pacific hake) and cephalopod remains (William Walker, personal communication), and yielded 57 otoliths (Table III, Fig. 3). Of the 43 hake otoliths, 29 were from fish that would have been

TABLE III. Numbers and kinds of otoliths found in the stomachs of *Lagenorhynchus obliquidens*, *Delphinus delphis*, and *Lissodelphis borealis* from southern California.

	No. of otoliths				
	Lagenorhynchus obliquidens		*Delphinus delphis*		
Kinds of fishes eaten	M-31-63[a]	M-26-67[a]	M-02-68[a]	RLB 69[b]	*Lissodelphis borealis*
Argentinidae					
Argentina sialis				3	
Bathylagidae					
Bathylagus sp.				1	
Batrachoididae					
Porichthys notatus				3	
Centrolophidae					
Icichthys lockingtoni					2
Engraulidae					
Engraulis mordax	4	12	127	14	
Melamphaidae					
Scopelogadus bispinosus					1
Merlucciidae					
Merluccius productus	3	43		97	2
Myctophidae					
Diaphus cf. *theta*			1		23
Lampadena urophaos					7
Lampanyctus cf. *ritteri*					5
Stenobrachius leucopsarus			3		
Tripholurus mexicanus					5
Unidentifiable myctophids					107
Ophidiidae					
Otophidium taylori				1	
Sciaenidae					
Seriphus politus		2			
Scomberesocidae					
Cololabis saira			2		
Total	7	57	133	119	152

[a]Accession number of Cetacean Research Laboratory, Little Company of Mary Hospital, Torrance, Calif.
[b]R. L. Brownell field number.

16–20 inches (400–500 mm) long, but the other 14 had come from smaller individuals (±8 inches or 200 mm long). These hake almost certainly had to be caught at a depth greater than 400 ft (120 m), and the anchovies may have been also, since all 12 otoliths represented large *Engraulis* (±7 inches or 180 mm), a size that typically inhabits depths of 400–650 ft (120–200 m). *Seriphus* is known only from relatively shallow (±30 m) inshore waters.

The other *L. obliquidens* (M-31-63) had stranded itself alive near the Santa Monica pier on August 29, 1963. In addition to the three *Merluccius* and four *Engraulis* otoliths, its stomach contained some cephalopod beaks and the fused pharyngeal tooth patch from a white seaperch, *Phanerodon furcatus*. *Phanerodon* is known only from relatively shallow (±30 m) inshore waters, but the hake and anchovies probably had been caught at a depth greater than 120 m.

FISHES EATEN BY *DELPHINUS DELPHIS*

Only two *D. delphis* stomachs (RLB 69, which was captured 4 miles off the San Pedro lighthouse between January and April 1964, and M-02-68, which was stranded alive at Zuma Beach on January 28, 1968) of many that Brownell examined contained otoliths. The 119 sagittae in the stomach of the 1964 dolphin represented a minimum of 63 fish belonging to six species in six families (Table III, Fig. 3). All of these fish could have been caught at or near the bottom in 650–800 ft (200–250 m) of water. None, including the hake, was very large, possibly 10 inches (250 mm) long, and weighing an ounce or so (±30 g). Five of these (*Argentina*, *Bathylagus*, *Merluccius*, *Otophidium*, and *Porichthys*) had not been reported among *D. delphis* food items previously.

The stomach of the Zuma Beach *Delphinus* contained 133 otoliths representing a minimum of 72 fish belonging to four species in three families and four genera. The Pacific saury, *Cololabis saira*, had to be taken at the surface, but the two lanternfishes and the anchovies probably were captured at least 600 ft (200 m) beneath the surface.

FISHES EATEN BY *LISSODELPHIS BOREALIS*

On November 8, 1967, an adult *L. borealis* was stranded near Imperial Beach, California, and Carl L. Hubbs, Scripps Institution of Oceanography, who examined the specimen, sent us 152 otoliths he washed out of the folds of its stomach along with "a multitude of squid beaks and lenses" (Carl L. Hubbs, personal communication). Most of these otoliths were digested considerably, but this did not preclude their identification to family, and in many cases to genus and species. Lanternfish otoliths representing at least four species (Table III, Fig. 3) comprised nearly 97% of the 152 sagittae. Less than a dozen of the 107 badly eroded otoliths that we identified only as myctophids (Table III) were of a type peculiar to *Lampanyctus*, whereas the others resembled *Diaphus* in size and configuration, but their state of digestion did not permit positive generic determinations. Possibly all seven species

known to be represented had been captured and eaten at least 650 ft (200 m) beneath the surface, although 5½-inch (135 mm) *Icichthys lockingtoni* are most abundant in the uppermost 150 ft (45 m).

FISHES EATEN BY *PHOCOENA SINUS*

The Gulf of California harbor porpoise was first described by Norris and McFarland in 1958, and to date only two entire specimens appear to have been collected (R. L. Brownell, unpublished data). Nothing has been reported in the literature on their food habits or other aspects of biology, and little is known of their behavior and distribution (Norris and Prescott, 1961). The stomach of one of the two complete specimens, an adult female (RLB 338), was examined on the beach about 20 km north of San Felipe, Baja California Norte, Mexico, on April 2, 1967. It contained 18 otoliths in rather poor condition, yet sufficient characteristics remained that the otoliths could be identified as having come from two species of shallow-water bottom-dwelling fishes. Thirteen of the otoliths (seven left and six right) were from the grunt *Orthopristis reddingi*, and five (three right and two left) were from the croaker *Bairdiella icistius* (Fig. 3). Both of these fishes are abundant throughout the upper Gulf of California; neither attains any great size, *Orthopristis* reaching perhaps 8 inches (200 mm), and *Bairdiella* possibly 10 (250 mm).

GENERAL DISCUSSION

From 18,164 otoliths found in the stomachs of 17 cetaceans, we determined that 18 kinds of fish had been eaten by *Kogia simus*, 16 kinds by *Stenella longirostris*, 9 by *Delphinus delphis*, 7 by *Stenella graffmani*, 7 by *Lissodelphis borealis*, 3 by *Lagenorhynchus obliquidens*, and 2 by *Phocoena sinus*. In addition we speculated on the sizes of fishes preyed upon as well as probable depth of feeding. On the basis of conventional recognition characters, only two fish species could have been identified: *Oxyporhamphus micropterus* in *Stenella graffmani* M-32-67, and *Merluccius productus* in *Lagenorhynchus* M-26-67.

Numerous well-documented accounts show that there is a direct relationship between otolith length and fish length for each species (Sastry, 1936; Fairbridge, 1951; Southward, 1962; Southward and Chapman, 1965; and many others). Thus, if one has accumulated this information for a given prey species, and undigested otoliths of that species have been found in the stomach of a predator, the lengths of the fishes eaten can be estimated reliably. Similarly, a reliable estimate can be obtained of the poundages ingested by utilizing a weight–length curve for the species in question.

There has been much speculation on whether the otoliths found in the folds of cetacean stomachs represent the remains of a single meal, or are an accumulation from several days of feeding. In our opinion, not even the 15,191 otoliths (representing more than 7596 fishes) reported by Schmidt (1923) represented a "full" meal for the *Delphinus* that they came from. We base this conclusion on the fact that it takes from 7000 to 10,000 adult *Benthosema*

panamense to fill a gallon jar, which is a much smaller volume than a distended dolphin stomach. Thousands of *B. panamense* otoliths were found in the *Stenella* stomachs we investigated, and these lanternfishes are similar in size to the myctophids eaten by Schmidt's *Delphinus*.

In these days of extensive porpoise research, it would be a simple matter to design experiments that would produce answers as to how long cetaceans retain fish otoliths in their stomachs. Once a rate of digestion has been determined, details regarding periodicity of feeding could be worked out with a high degree of accuracy.

We feel certain that three of the cetaceans we investigated (*Kogia simus*, *Stenella longirostris*, and *Lissodelphis borealis*) had been feeding 800 ft (250 m) or more beneath the surface, and that two others (*Lagenorhynchus obliquidens* and *Delphinus delphis*) had descended to depths exceeding 400 ft (120 m). On the other hand, *Stenella graffmani* and *Phocoena sinus* appear to have fed within 100 ft (30 m) of the surface, and probably even shallower.

At least 8 of the 16 species fed upon by *Stenella longirostris* are known to ascend into (or nearly into) surface waters at night, but we doubt if the spinner dolphin did much foraging for food in these upper water layers. Trawl nets towed in these surface waters at night usually yield rather poor catches of myctophids and other mesopelagic vertical migrators, an indication that population densities are too sparse to supply either the diversity of species or numbers of individuals that made up the spinner's food. Similar logic applies to *Lissodelphis*, and the bottom-dwelling morid and macrourid remains found in the *Kogia simus* stomachs are proof of its deep-diving ability.

We have been impressed with the apparent dependency of the smaller cetaceans on mesopelagic fishes, especially myctophids, which are generally conceded as being one of the most widespread and abundant, yet least utilized, fish families in the world oceans. If the day ever arrives that man finds it economically feasible to harvest fishes from the scattering layers, uncontrolled exploitation could have a disastrous effect on our dolphin, porpoise, and whale populations.

ACKNOWLEDGMENTS

This investigation was supported in part by the National Science Foundation (NSF) through grants to Fitch (GB-1244 and GB-6490) for his research on otoliths. Brownell's work in Japan was made possible through a grant from the NSF to David K. Caldwell (GF-241) for cetacean studies, and while working at the Cetacean Research Laboratory, Little Company of Mary Hospital, Brownell received financial assistance through research grant HE 07146 from the National Heart Institute through the U.S. Public Health Service. Brownell received additional assistance from Toshio Kasuya through a grant from the Japan Society for Promotion of Science, which with the NSF co-sponsors the U.S.–Japan Cooperative Science Program.

Many individuals contributed ideas, information, specimens, or their talents, including the following: Jules Crane, Cerritos College; C. H. Fiscus,

U.S. Fish and Wildlife Service, Marine Mammal Biological Laboratory, Seattle, Wash.; John Geibel, California Department of Fish and Game, Terminal Island; Spano Giacalone, San Diego; Charles O. Handley, Jr., U.S. National Museum; Carl L. Hubbs, Scripps Institution of Oceanography; Robert J. Lavenberg, Los Angeles County Museum of Natural History; John Paxton, University of Southern California; Dale W. Rice, U.S. Fish and Wildlife Service, Seattle; Victor B. Scheffer, U.S. Fish and Wildlife Service, Seattle; Jack W. Schott, California Department of Fish and Game, Terminal Island; John Seapin, California Department of Fish and Game, Terminal Island; and William Walker, Cetacean Research Laboratory, Little Company of Mary Hospital, Torrance.

REFERENCES

BEST, E. A. 1963. Contribution to the biology of the Pacific hake, *Merluccius productus* (Ayres). Cal. Coop. Ocean. Fish. Invest. Rept., **9**: 51–56.

BROWN, DAVID H., AND KENNETH S. NORRIS. 1956. Observations of captive and wild cetaceans. J. Mammal., **37**(3): 311–326.

CADENAT, J. 1959a. Notes sur les Delphinidés ouest-africains. VI. — Le gros Dauphin gris (*Tursiops truncatus*), est-il capable de faire des plongées profondes? Bull. Inst. Franc. Afrique Noire, Ser. A, **21**(3): 1137–1141.

1959b. Rapport sur les petits Cétacés ouest-africains. Résultats des recherches entreprises sur ces animaux jusqu'au mois de mars 1959. Ibid., **21**(4): 1367–1440.

CADENAT, J., AND M. DOUTRE. 1959. Notes sur les Delphinidés ouest-africains. V. — Sur un *Prodelphinus* à long bec capturé au large des côtes du Sénégal, *Prodelphinus longirostris* (Gray) 1828 Ibid., **21**(2): 777–798.

DAUGHERTY, ANITA E. 1965. Marine mammals of California. Calif. Dept. Fish. Game Sacramento, Calif. 87 p.

FAIRBRIDGE, W. S. 1951. The New South Wales tiger flathead, *Neoplatycephalus macrodon* (Ogilby). I. Biology and age determinations. Australian J. Marine Freshwater Res., **2**(2): 117–178.

FISCUS, CLIFFORD H., AND KARL NIGGOL. 1965. Observation of cetaceans off California, Oregon, and Washington. U.S. Fish Wildlife Serv., Spec. Sci. Rept. Fish., **498**: 27 p.

FROST, G. A. 1924. Fish otoliths from the stomach of a porpoise. Nature, **113**(2835): 310.

HAEDRICH, RICHARD L. 1967. The stromateoid fishes: systematics and a classification. Bull. Museum Comp. Zool., **135**(2): 31–139.

NAFPAKTITIS, BASIL, AND JOHN PAXTON. 1968. Review of the lanternfish genus *Lampadena* with a description of a new species. Los Angeles Co. Museum, Contrib. Sci., **139**: 29 p.

NORRIS, KENNETH S., AND W. N. MCFARLAND. 1958. A new harbor porpoise of the genus *Phocoena* from the Gulf of California. J. Mammal., **39**(1): 22–39.

NORRIS, KENNETH S., AND JOHN H. PRESCOTT. 1961. Observations on Pacific cetaceans of California and Mexican waters. Univ. Calif. Publ. Zool., **63**(4): 291–402.

SASTRY, N. S. 1936. The relation of the age to the length of a fish and the length of its otoliths. J. Madras Univ., **8**: 200–207.

SCHEFFER, VICTOR B., AND JOHN W. SLIPP. 1948. The whales and dolphins of Washington State with a key to the cetaceans of the west coast of North America. Am. Midland Naturalist, **39**(2): 257–337.

SCHMIDT, JOHANNES. 1923. Consumption of fish by porpoises. Nature, **112**(2825): 902.

SCOTT, THOMAS. 1903. Some further observations on the food of fishes, with a note on the food observed in the stomach of a common porpoise. Twenty-first Ann. Rept. (1902) Fish. Bd. Scotland, Pt. III, Sci. Invest. p. 218–227.

SOUTHWARD, G. MORRIS. 1962. A method of calculating body lengths from otolith measurements for Pacific halibut and its application to Portlock-Albatross grounds data between 1935 and 1957. J. Fish. Res. Bd. Canada, **19**(2): 339–362.

SOUTHWARD, G. MORRIS, AND D. G. CHAPMAN. 1965. Utilization of Pacific halibut stocks: study of Bertalanffy's growth equation. Rept. Intern. Pacific Halibut Comm., **39**: 1–33.

VLADYKOV, VADIM D. 1946. Etudes sur les mammifères aquatiques. IV. — Nourriture de Marsouin Blanc ou Béluga (*Delphinapterus leucas*) du fleuve Saint-Laurent. Contrib. Québec Dépt. Pèch., **17**: 157 p.

Some Physical and Chemical Characteristics of Arctic Fresh Waters In Alaska and Northwestern Canada[1]

By J. Kalff

Department of Zoology
McGill University, Montreal, Que.

ABSTRACT

Fifty-eight Arctic Alaskan lakes and rivers and two ponds as well as a few northwestern Arctic Canadian waters were analyzed for two or more physical or chemical characteristics. The waters sampled were nearly all of the bicarbonate type and ranged from very soft to hard. The Alaskan and mainland Canadian lakes contain levels of many ions similar to those of some low electrolyte lake waters previously reported for the north temperate zone. The characteristics measured, with the mean values for the Alaskan waters in brackets when 20 or more lakes or rivers were sampled, were: calcium (17.2 mg/liter), magnesium (2.1 mg/liter) total iron, total alkalinity (50.3 mg/liter), sulfate (4.9 mg/liter), chloride (3.8 mg/liter), nitrate, phosphate, electrical conductance (116 μmho), *p*H (7.7), and water color (24 Pt units). One of the ponds, analyzed for 18 trace metals, indicated relatively high concentrations of iron manganese, zinc, and copper. Correlation coefficients (r at $P < 0.5$) between various characteristics were: electrical conductance and total alkalinity, 0.98; electrical conductance and calcium, 0.97; electrical conductance and magnesium, 0.42; calcium and magnesium, 0.46; and *p*H and total alkalinity, 0.91. On the Coastal Plain of Arctic Alaska the total electrolyte content of lakes lying within 25–50 km from the Arctic Ocean was noticeably raised by chloride additions.

INTRODUCTION

Recent limnological studies in Arctic Alaska have yielded chemical data for single lakes or for small regions (Livingstone, 1963a; Brown et al., 1962; Boyd and Boyd, 1958; Lamar, 1966; Watson et al., 1966), but only Holmquist (1967) listed data from lakes located in different areas of Arctic Alaska.

The purpose of the present study was to characterize the fresh waters of the Arctic Slope of Alaska and the relationships between the concentrations of a number of the ions present.

The field work was largely done during the summer, between July 1962 and September 1964, in conjunction with limnological research in the Barrow area (Kalff, MS, 1965, 1967a, b). One surface sample from each of 58 Alaskan waters (Fig. 1) and a small number of samples from northwestern mainland Canada and Banks Island, N.W.T., were analyzed.

There are no published chemical analyses of rivers originating in the North American Arctic and flowing north towards the Arctic Ocean although chemical analyses have been done on some Arctic Alaskan rivers flowing in a southerly or western direction in the southern section of the Foothills province (Lamar, 1966). In the present study a number of analyses were done on the Colville River and its tributaries and a few other Arctic rivers.

[1]Received for publication May 9, 1968.

J. Fish. Res. Bd. Canada, 25(12): 2575–2587, 1968.
Printed in Canada.

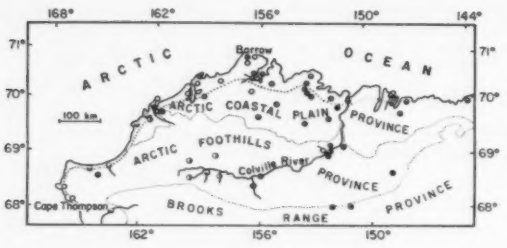


FIG. 1. Distribution in Arctic Alaskan surface waters of total alkalinity as $CaCO_3$: ○, <20 mg/liter; ◑, 21–40; ◒, 41–84; ●, >84. Crosshatched line (××××) approximates the 5 mg/liter isochlor.

The Alaskan lakes and streams studied (Fig. 1, Tables II, IV) lie with few exceptions on the Arctic Slope of Alaska, which is in the region between the crest of the Brooks Range and the Arctic Ocean. The Arctic Slope was divided by Payne et al. (1951) into three physiographic provinces — the Brooks Range, the Foothills, and the Coastal Plain (Fig. 1). The Brooks Range province is formed of sedimentary rock of Paleozoic age and includes limestone, shale, chert conglomerate, and sandstone. The northern section of the Foothills province, a belt of rolling hills north of the Brooks Range with elevations generally of 150–650 m, is composed of marine and nonmarine cretaceous rocks and includes shale, limestone, sandstone, conglomerate, bentonite, and tuff. The Coastal Plain province, which has not been glaciated, is underlain by a mantle, seldom thicker than about 30 m, of marine silts, sand, and gravel of the Pleistocene Gubik formation. This formation overlies gently folded Mesozoic and Paleozoic strata.

In the Barrow area the stratum of summer thaw, the "active layer," lies over 300 m of permafrost (MacCarthy, 1952). Soils of the Arctic Slope have been studied largely by Tedrow and his students (see Douglas and Tedrow, 1960).

The climate of the Arctic Slope is characterized by short, cool summers and long winters. Near the coast, as at Barrow, the summers are somewhat cooler and the winter somewhat milder than further inland. The mean annual precipitation is only 11.6 cm (4.55 inches) (United States Weather Bureau, 1964) and rises to about 46 cm (18 inches) at 650 m along the central part of the slope (Conover, 1960). The mean relative humidity at Barrow during June, July, and August is 89% at 1400 AST, and the mean windspeed during the same period is 5.5 m/sec. (11.93 mph) (United States Weather Bureau, 1964).

The great abundance of ponds, lakes, and meandering streams on the Coastal Plain and lower Foothills is favored by the shallow "active layer," which has a maximum depth, reached in late summer, of usually less than 45 cm (Drew and Tedrow, 1962) by the high summer humidity over the Slope and by the low gradient of the land. Black and Barksdale (1949) estimated that in the western portion of the Coastal Plain water covers 50–75% of the land and in some areas as much as 90% of the land. Most of the lakes on the Coastal Plain are shallow with depths of no more than 5 m

(Prescott, 1963). Lakes are generally deeper in the Foothills and Brooks Range but depths greater than 20 m appear uncommon (Holmquist, 1967). The Coastal Plain and Foothill lakes do not normally exhibit a summer temperature stratification (C. Holmquist, personal communication), although temporary thermal stratifications develop in some of the deeper and sheltered mountain lakes (Hobbie, 1961).

The Alaskan lakes are usually ice-free for about 2 months of the year, from mid-July to the middle or end of September (Hobbie, 1961; Boyd, 1959; Brewer, 1958). A maximum ice cover of approximately 2 m is present in early May. The many small, shallow, polygonal tundra ponds near Barrow, Alaska are ice-free from early June to early September (Kalff, 1967a). The largest river in the study area, the Colville River, drains about 50,000 km^2 of the Arctic Slope and has an annual discharge of approximately 16×10^9 m^3 year but does not flow in late winter (Arnborg et al., 1966).

METHODS

Samples for chemical analysis were collected in plastic bottles just below the water surface and analyzed at the Arctic Research Laboratory, Barrow, Alaska.

Procedures used for the determination of the total alkalinity, *p*H, electrical conductivity, calcium, and magnesium as well as chloride concentration and water color have been reported (Kalff, 1967b). Turbidity was ascertained with a Hellige turbidimeter. A Klett–Summerson photoelectric colorimeter with a 4-cm light path was used to determine phosphate phosphorus by the stannous chloride method at maximum color development (Dobie and Moyle, 1956) after filtration through Whatman No. 42 filter paper. Nitrate nitrogen was determined by the phenoldisulfonic acid method (Dobie and Moyle, 1956) after filtration, and iron by the phenanthroline method (American Public Health Association, 1960) modified by using hydroquinone as a reducing agent and sulfates by turbidimetry (Dobie and Moyle, 1956). An estimate of dissolved organic matter was obtained by treating the Whatman No. 42-filtered water with potassium permanganate (Mackereth, 1963).

RESULTS AND DISCUSSION

The initial determination of the regression of the total alkalinity as mg/liter $CaCO_3$ on the specific conductance demonstrated that most coastal lakes, making up half the total waters analyzed, had a specific conductance greater than the total alkalinity suggested. A relatively high chloride level indicated that these waters were appreciably influenced by the ocean. Deviations from the initially plotted regression line were evident at chloride levels greater than 5 mg/liter and such waters were therefore arbitrarily omitted from Table I and when relationships between ions were determined. The omitted lakes lie in a belt approximately 25–50 km wide in northwest Alaska, with the maximum width southwest and east of Barrow (Fig. 1). Holden (1961) noted

TABLE I. *p*H, water color, electrical conductance, and ionic compositions (mg/liter) of Arctic Alaskan rivers and lakes 1962–64, with the world means for the ions in river waters. Numbers of waters sampled in parentheses.

	Range	Mean	Median	World mean[a]
*p*H	6.9–9.2(34)	7.7	7.7	
Water color (*Pt units*)	10–70(20)	24	20	
Electrical conductance (*μmhos at 25 C*)	22.–274.(33)	116	100	
Ca	2.8–35.8(27)	17.2	12.6	15.0
Mg	0.1–9.0(26)	2.1	1.9	4.1
Total alkalinity as $CaCO_3$	7–115(34)	50.3	36.7	58.4
SO_4	0.0–30(20)	4.9	0.6	11.2
Cl	0.0–24.2(27)	3.8	2.1	7.8

[a]Livingstone (1963b).

that in Scotland too the chloride concentration of lakes generally varied with the distance from the coast. A few samples collected in the Cape Thompson area (68°N, 165°W), as well as three ponds studied in that area by Watson et al. (1966), suggest that where hills of the Arctic Foothill province border the sea the influence of the ocean on the ionic composition of the lakes and ponds becomes negligible at approximately 10 km from the coast.

That sea spray can contribute chloride and other electrolytes to fresh water near the coast has been shown by a number of workers (e.g. Gorham, 1961). However, the Arctic Ocean near the coast is frozen from late October to the middle of July, restricting the contribution of ions to lakes largely to a 3-month period. The absence of a significant tide also limits the amount of spray carried inland to periods of high northerly and westerly winds. Nevertheless, air masses moving across the Arctic Ocean pick up electrolytes, which are deposited on land during precipitation. On August 1, 1964, in the absence of appreciable wave action, precipitation at Barrow had 4.4 mg/liter Cl, 1 mg/liter total alkalinity, a trace of SO_4, 0.04 mg/liter NO_3, 0.009 mg/liter PO_4, a trace of Ca, 0.05 mg/liter Mg, 0.02 mg/liter Fe, an electrical conductivity of 22, and a *p*H of 4.5. Aerial transport of electrolytes had raised the chloride concentration of coastal Teshekpuk Lake (70°35′, 153°30′W), the region's largest lake with a maximum length and width of approximately 45 × 33 km, to 18.9 mg/liter in August 1963.

The Arctic Slope fresh waters not appreciably influenced by the ocean (Table I) as well as those analyzed in mainland Canada and on Banks Island (Tables II, IV) are of the bicarbonate type, characterized by the predominance of Ca among the cations and HCO_3 among the anions. That the total alkalinity largely reflects the concentration of bicarbonate ions was indicated by the *p*H of all the samples, which ranged, with one exception, between 6.2 and 8.4. The exception was a relatively hard-water unnamed Alaskan lake (69°32′N,

TABLE II. Electrical conductance, *p*H, water color, turbidity, and ionic compositions (mg/liter) for some lakes in the Arctic Slope of Alaska and mainland Canada.

Lake	Location	Date collected	Conductance (*μmho at 25 C*)	*p*H	Color (*Pt units*)	Turbidity (*mg/liter*)	Ca	Mg	Fe	Total alkalinity as $CaCO_3$	SO_4	Cl	NO_3	PO_4
Alaska														
Iroavik L.[a]	71°14′N 156°38′W	July 5, 1964	148	6.7	30	0.9	4.4	2.7	0.14	9	0.4	–	0.020	0.018
(Unnamed)[a]	70°86′N 147°40′W	Aug. 3, 1964	178	8.0	25	1.7	29.8	1.4	0.07	74	0.0	10.6	0.020	0.003
E. Oumalik L.[a]	69°50′N 155°27′W	Aug. 17, 1964	273	8.3	20	1.8	34.2	5.3	–	107	2.2	24.2	<0.010	0.002
(Unnamed)[a]	69°42′N 151°59′W	"	196	8.3	20	1.2	34.6	1.6	–	96	0.0	8.5	<0.010	0.004
Square L.[a]	69°36′N 153°15′W	"	273	8.4	20	1.9	3.9	1.1	–	115	4.3	16.9	<0.010	0.005
(Unnamed)[a]	69°33′N 162°16′W	July 24, 1964	126	7.7	25	–	16.5	4.4	0.02	54	0.0	11.7	0.020	0.009
Northwest Territories														
(Unnamed)[b]	73°25′N 121°55′W	Aug. 2, 1963	288	8.2	15	–	29.4	18.7	–	138	5.5	7.2	–	–
Sitidgi L.[b]	68°32′N 132°40′W	Aug. 11, 1964	95	7.3	–	–	9.3	–	0.02	16	18.0	–	0.015	0.006
Canoe L.[b]	68°14′N 135°54′W	Aug. 12, 1964	43	7.1	–	–	4.0	–	0.18	10	15.0	–	0.020	0.008
Noell L.[b]	68°32′N 133°34′W	Aug. 9, 1964	65	7.3	25	–	6.0	2.5	0.01	16	5.7	5.4	0.010	0.004
Travaillant L.[b]	67°40′N 131°47′W	Aug. 13, 1964	109	7.8	25	–	12.4	5.9	0.10	60	12.4	5.9	0.010	0.004
Yukon														
(Unnamed)[b]	68°12′N 139°23′W	Aug. 12, 1964	142	8.1	30	–	23.9	3.4	0.02	72	0.0	–	0.010	0.004
(Unnamed)[b]	66°20′N 135°15′W	Aug. 10, 1964	20	6.9	>70	–	3.0	0.7	0.12	8	0.0	–	0.060	0.005
Margaret L.[b]	65°21′N 134°30′W	Aug. 10, 1964	74	7.7	45	–	8.9	4.0	0.02	44	1.0	1.7	0.030	0.004

[a]Analysis done on the date of collection.
[b]Analysis done within 3 days of collection.

151°15′W) with extensive beds of *Chara* sp. (C. Holmquist, personal communication) and a *p*H of 9.2. According to the expanded standard Wisconsin categories of Brooks and Deevey (1963) (HCO_3 < 10 mg/liter, extremely soft; 10–27, soft; 28–84, medium-hard; <84, hard), arctic Alaskan lakes and rivers range between extremely soft and hard (Table I) with the mean and median indicating the waters to be medium-hard. Moyle (1954) characterized Minnesota lakes with a total alkalinity lower than 40 mg/liter as soft-water lakes. Such lakes had low inorganic nutrient levels, sparse aquatic vegetation, and a low standing stock of fish. Although the mean total alkalinity of the Alaskan lake and river waters was higher than 40 mg/liter (Table I) two-thirds of all the lakes sampled (Fig. 1) fell in Moyle's category of soft-water lakes.

The mean level of calcium in the sampled lakes and rivers is approximately that of the average for the rivers of the world (Table I), whereas magnesium is present in much smaller concentration than the world average.

The mean sulfate and chloride levels obtained for Arctic Alaska, omitting samples influenced by the ocean, are considerably lower than the mean for the world. However, the latter includes fresh water influenced by the oceans. The two most important exceptions to the low chloride levels are high-electrolyte Oumalik Lake (69°50′N, 155°27′W) and Square Lake (69°36′N, 153°15′W) in the Foothills with 24.2 and 16.9 mg/liter Cl respectively, on August 17, 1964 (Table II). Low-sulfate waters are characteristic of the Arctic Slope of Alaska, but many waters in the Cape Thompson area of the southern section of the Foothills province contain much higher levels of sulfates (Lamar, 1966).

Many of the Alaskan waters had a fairly high water color (Table I), a feature they have in common with many Arctic Coastal Plain waters in Canada (Thomas, 1964). Tundra ponds commonly have a very high water color, Livingstone (1963a) having reported values of up to 250 Pt units for Alaskan tundra ponds. An even higher water color was recorded in a Barrow area pond (Table III) in midsummer. Alaskan lakes usually contained between 10 and 30 Pt units.

Forsberg (1967) found a high correlation between water color and levels of dissolved organic carbon in some lakes in Uppland, Sweden. Using his derived equation for the estimation of dissolved organic carbon from the water color in lakes containing less than 100 Pt units, the average for 20 Alaskan lakes and rivers (Table I) suggests dissolved organic carbon levels of approximately 8 mg/liter.

Significant correlations were found, at $P < 0.05$, between electrical conductance and total alkalinity ($r = 0.98$), electrical conductance and calcium ($r = 0.97$), electrical conductance and magnesium ($r = 0.42$), calcium and magnesium ($r = 0.46$), and total alkalinity and *p*H ($r = 0.91$) of Alaskan samples analyzed on the day of collection. The last correlation indicated that with the exception of the lake with extensive *Chara* beds, the recorded *p*H values largely reflected physical–chemical equilibria and were not significantly influenced by biological processes.

TABLE III. *p*H, water color, dissolved organic matter, turbidity, electrical conductance, and ionic compositions (mg/liter) of two Barrow area ponds between July 2 and August 18, 1964. Numbers of samples given in parentheses. Analyses were done on day of collection.

Element	Pond II		Pond III	
	Mean	Range	Mean	Range
*p*H	6.9(17)	6.7–7.2	7.1(17)	6.9–7.2
Color (*Pt units*)	171(9)	160–220	318(9)	200–400
Dissolved organic matter (*mg O2 liter*)	33.5(8)	14.2–36.2	36.5(9)	33.4–42.9
Turbidity	1.8(8)	1.1–2.5	5.9(8)	3.5–7.5
Electrical conductance (*μmho at* 25 C)	197(9)	132–248	174(9)	138–201
Ca	7.9(9)	5.0–10.2	10.0(9)	6.8–12.8
Mg	5.1(9)	3.0–8.2	5.4(9)	3.6–6.9
Fe (total)	0.9(4)	0.5–1.4	2.1(4)	0.8–2.6
Total alkalinity as $CaCO_3$	17.4(17)	12–24	30.2(17)	21–37
SO_4	trace(9)	0–01	0.1(9)	0–1.2(?)
Cl	44.8(9)	30.2–58.8	39.1(8)	30.9–41.1
NO_3	0.09(8)	0.05–0.12	0.14(8)	0.10–0.17
PO_4	0.006(10)	0.002–0.013	0.013(10)	0.008–0.019

With the exception of the regression of magnesium on the electrical conductance, the calculated regression lines are very similar to the lines of relationship for the "standard composition" determined by Rodhe (1949) for calcareous water after converting his conductance values at 20 to 25 C following Rainwater and Thatcher (1960). However, the Alaskan waters sampled generally contained more calcium (Fig. 2) at equivalent electrical conductance levels than the "standard composition." The correlation coefficient ($r = 0.46$, $P < 0.05$) between levels of calcium and magnesium indicated considerable variability in the ratio of the two ions.

Although Na and K were not determined the almost identical relationship between the "standard composition" of bicarbonate and electrical conductance on the one hand and the Alaskan composition on the other suggests that the Alaskan fresh waters sampled that were not noticeably influenced by the ocean should have a mean concentration of approximately 4 mg/liter Na and 1.5 mg/liter K.

The lines of best fit calculated for the regression of the total alkalinity on the electric conductance (Fig. 2), calcium concentration on electrical conductance (Fig. 2), and to a much smaller extent magnesium concentration on electrical conductance (Fig. 3) allow the estimation of concentrations of the above ions when only one has been analyzed and also provide a quick check on the degree of ocean influence on particular coastal waters when both the total alkalinity and the electrical conductance have been determined. Any important deviations from the line of best fit for inland water would

TABLE IV. Specific conductance, *p*H, water color, and ionic compositions (mg/liter) of Arctic rivers in Alaska and northwestern Canada. The first four samples are from tributaries of the Colville River, Alaska.

River	Approx location	Date collected	Conductance (*μmho at 25 C*)	*p*H	Color (*Pt units*)	Ca	Mg	Alkalinity as $CaCO_3$	SO_4	Cl
Alaska										
Kiligwa R.	68°50′N 159° W	Early Sept. 1963	94	7.1	–	12.3	3.6	43.4	3.3	2.0
Wager Cr.	68°40′N 158°40′W	Early Sept. 1963	108	7.2	–	13.6	3.5	27.8	30	2.1
Etivulak R.	68°32′N 156°25′W	Mid-Aug. 1963	72	7.0	30	9.1	2.5	26.7	–	1.0
Seabe Cr. tributary	69°22′N 152°06′W	Early Aug. 1963	33	6.2	>70	5.1	1.3	10.0	–	1.0
Colville R.	70°14′N 150°50′W	Late Aug. 1963	105	7.2	40	14.7	3.2	29.0	–	1.0
Colville R.	70°14′N 150°50W′	Aug. 6, 1963	110	7.8	55	16.6	2.6	45.6	4.8	–
Noatak R.	67°52′N 162°40′W	July 13, 1963	136	7.8	25	21.1	3.1	54.1	22.0	1.0
Utokok R.	69°5′ N 161°5′W	Sept. 12, 1963	232	8.0	–	36.6	4.7	105.8	10.2	1.9
Inaru R.	70°58′N 156°30′W	Aug. 20, 1962	105	7.3	–	–	–	23.4	–	–
Northwest Territories										
Bernard R.	73°25′N 121°55′W	Aug. 3 1963	216	8.2	10	26.8	11.4	103.6	6.4	3.2
(Unnamed)	73°25′N 121°55′W	Aug. 3, 1963	239	8.1	10	30.2	11.9	111.4	11.4	1.4

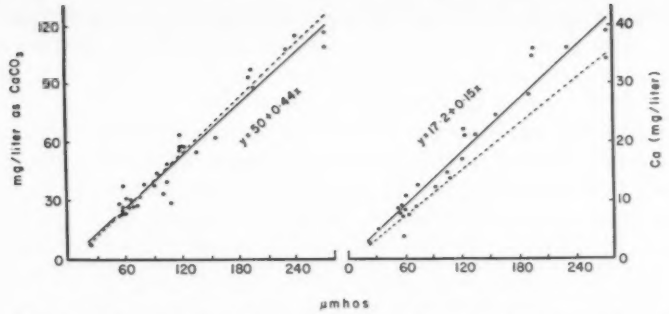


FIG. 2. Regression (*solid line*) of total alkalitity (mg/liter $CaCO_3$) and calcium (mg/liter) on electrical conductance (μmho at 25 C), determined by the least square method, in Arctic Alaskan surface waters sampled, and Rodhe's (1949) line of relationship (*broken line*) for the "standard composition" of calcareous waters.

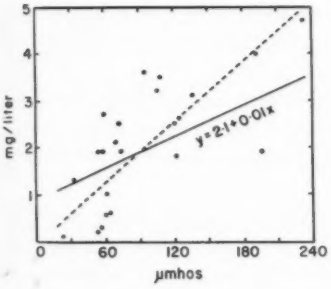


FIG. 3. Regression (*solid line*) of magnesium (mg/liter) on electrical conductance (μmho at 25 C), determined by the least square method, of Arctic Alaskan surface waters sampled, and Rodhe's (1949) line of relationship (*broken line*) for the "standard composition" of calcareous waters.

indicate unusually high levels of one or more other ions. One such deviation (Fig. 2) was the result of an unusually high chloride concentration which raised the conductance above the expected for the particular alkalinity to approximately 270 μmho.

Because of similarity between the "standard composition" and the composition of the Alaskan waters studied it was possible to estimate the mineral content of these waters. It ranged between 15 and 210 mg/liter with a mean of 84 mg/liter. If the Koyukuk River adjacent to Bettles Field (66°54′N, 151°45′W) in the southern Foothills, sampled on August 1, 1962, was included the upper range would be extended to 230 mg/liter (229 μmho). Only central Banks Island, N.W.T., had harder water, ranging between approximateiy 182 mg/liter in the Bernard River and 338 mg/liter in a small pond, with the latter value estimated by extrapolating the "standard composition" beyond the range determined by Rodhe (1949).

Some information was obtained on the levels of Fe, NO_3, and PO_4 in Arctic Slope and northwestern Canadian lakes (Table II). These and other minor elements were defined by Rodhe (1951) as those elements generally present at <1 mg/liter. Minor elements generally did not affect the electrical

conductivity of about 150 Swedish lakes because only a small part of the minor elements other than strontium were ionized and because some minor elements, such as nitrogen and phosphorus, are greatly influenced by biological events in the water (Rodhe, 1951).

Iron in the lakes (Table II) was, with one exception, lower than the mean concentration in North American river water of 0.16 mg/liter (Livingstone, 1963b). However, Fe in the two Barrow area ponds (Table III) was extremely high, with maxima of 2.6 mg/liter on August 12 in pond III and 1.5 mg/liter on July 31, 1964 in less heavily stained pond II. These concentrations are higher than most other values reported by Hutchinson (1957) for organic waters. Furthermore, most organic waters having a high iron content are below neutrality, whereas these ponds were neutral or slightly alkaline. The gradual increase in iron during the summer appeared to be associated with an increase in dissolved organic matter as measured with the permanganate test. On July 2 and 22, 1964, 55 and 67% respectively of the iron in pond III passed through 0.48-μ membrane filters, indicating that nearly half the iron was associated with larger particles. Other high iron values have been recorded in ponds high in organic matter in the Cape Thompson area (Watson et al., 1966).

The limited analyes for nitrate and phosphate indicate little about common levels of these ions in Arctic Alaskan fresh waters, except that the concentrations appear higher in the two highly stained ponds (Table III) than in lakes (Table II).

The lake PO_4 levels are not very different from a mean of 0.003 mg/liter soluble phosphorus recorded in the surface water of nearly 500 northeastern Wisconsin lakes (Juday and Birge, 1931) nor from the range of approximately 0.001–0.003 mg/liter given for most relatively uncontaminated surface waters in lake districts of the temperate zone (Hutchinson, 1957).

The NO_3 concentrations too are similar to those found in most northeastern Wisconsin lakes where Juday et al. (1938) recorded nitrate levels between 0.010 and 0.024 mg/liter in 81% of 472 lakes examined. Only the three Alaskan Foothill lakes had less than 0.01 mg/liter (Table II). Filtration through 0.48-μ membrane filters did not reduce the level in the filtrate on June 30, 1964. In contrast when pond III water was filtered in the same manner on June 30, 1964, half the phosphate was removed indicating that, in contrast to nitrate nitrogen, much of the phosphate was adsorbed to or complexed with particulate organic matter.

Trace metal concentrations of pond III water filtered through a 0.48-μ membrane filter can be compared with some trace metal levels measured in a few Arctic Alaskan lakes by Barsdate (1966). The limited comparison possible between the lakes (Barsdate, 1966) and pond III indicated considerably higher levels of dissolved zinc, iron, manganese, and copper in the pond than in the lakes, and the pond also had an unusually high ratio of Fe to Mn (Kopp, personal communication). Barsdate (1966) also determined concentrations in unfiltered water which indicated that a considerable amount of at least

cobalt, iron, and manganese was associated with particulate matter larger than approximately 0.5 μ (Table V).

The result of the chemical analysis of the arctic water indicates that most of the Alaskan and the mainland Canadian lakes sampled contain levels of most major electrolytes similar to those of some low electrolyte lake waters (Hutchinson, 1957) of the north temperate zone.

TABLE V. Trace element levels (μg/liter) in pond III near Barrow, Alaska, 1964 after membrane filtration (ca. 0.5 μ) and average concentrations of membrane filtered (ca. 0.5μ) and unfiltered surface water from some much less colored Arctic Alaskan lakes in 1965 (Barsdate, 1966). Numbers of lakes given in parentheses.

Element	Pond III filtered		Arctic lakes	
	June 22	Aug. 3	Filtered July 31	Unfiltered Aug. 4
Aluminium	3	3		
Arsenic	<40	–		
Barium	13	18		
Beryllium	<0.03	<0.03		
Boron	31	37		
Cadmium	<2	<3		
Chromium	<1	–		
Cobalt	<3	<3	3.5	4.7(8)
Copper	14	–	1.8	2.2(3)
Iron	1500	–	36	75(8)
Lead	<5	–	0.67(5)	–
Manganese	21	54	1.6	10.2(8)
Molybdenum	<5	5		
Nickel	<3	–		
Silver	<0.3	<0.3		
Strontium	11	25		
Vanadium	<5	<5		
Zinc	55	–	3.2(2)	

ACKNOWLEDGMENTS

I thank Dr Charlotte Holmquist, other investigators, and pilots based at the Arctic Research Laboratory, Barrow, Alaska, for collecting a large number of the water samples; Dr M. C. Brewer and staff of the Arctic Research Laboratory for logistic support; Mr M. C. Miller for laboratory assistance; and Dr J. F. Kopp, United States Public Health Service, Cincinnati, Ohio, for the trace metal analyses. The research was partially supported by National Science Foundation Grant GB-49 to Dr D. G. Frey, Indiana University.

REFERENCES

AMERICAN PUBLIC HEALTH ASSOCIATION. 1960. Standard methods for the examination of water and waste water including bottom sediments and sludges. 11th. ed. APHA, New York. 626 p.

ARNBORG, L., H. J. WALKER, AND J. PEIPPO. 1966. Water discharge in the Colville River, Alaska, 1962. Geography Ann., 48A: 195–210.

BARSDATE, R. J. 1966. Pathway of trace elements in arctic lake ecosystems. Ann. Progr. Rept. U.S. Atomic Energy Comm., contract AT (04-3)-310. 43 p.

BLACK, R. F., AND W. L. BARKSDALE. 1949. Oriented lakes of northern Alaska. J. Geol., **57**: 105–118.

BOYD, W. L. 1959. Limnology of selected arctic lakes in relation to water-supply problems. Ecology, **40**: 49–54.

BOYD, W. L., AND J. W. BOYD. 1958. Water supply problems at Point Barrow. J. Am. Water Works Assoc., **51**: 890–896.

BREWER, M. C. 1958. The thermal regime of an arctic lake. Am. Geophys. Union, **39**: 278–284.

BROWN, J., C. L. GRANT, F. C. UGOLINI, AND J. C. F. TEDROW. 1962. Mineral composition of some drainage waters from Arctic Alaska. J. Geophys. Res., **67**: 2447–2453.

BROOKS, J. L., AND E. S. DEEVEY, JR. 1963. New England. *In* D. G. Frey [ed.] Limnology of North America. Univ. Wisc. Press, Madison, Wisc. p. 117–162.

CONOVER, J. H. 1960. Macro- and microclimatology of the Arctic Slope of Alaska. Tech. Rept. EP-139, Quartermaster Res. Eng. Center, Natick, Mass. 69 p.

DOBIE, J., AND J. MOYLE. 1956. Methods used for investigating productivity of fish-rearing ponds in Minnesota. Minn. Dept. Conserv., Fish. Res. Unit, Spec. Publ. 5. 54 p.

DOUGLAS, L. A., AND J. C. F. TEDROW. 1960. Tundra soils of Arctic Alaska. 7th Intern. Congr. Soil Sci., **41**: 291–304.

DREW, J. V., AND J. C. F. TEDROW. 1962. Arctil soil. Classification and patterned ground. Arctic, **15**: 109–116.

FORSBERG, C. 1967. Dissolved organic carbon in some lakes in Uppland, Sweden. Oikos, **18**: 210–216.

GORHAM, E. 1961. Factors influencing the supply of major ions to inland waters, with special reference to the atmosphere. Geol. Soc. Am. Bull., **72**: 795–840.

HOBBIE, J. E. 1961. Summer temperature in Lake Schrader, Alaska. Limnol. Oceanog., **6**: 326–329.

HOLDEN, A. V. 1961. Concentration of chloride in freshwater and rain water. Nature, **192**: 961–962.

HOLMQUIST, C. 1967. Turbellaria of Northern Alaska and Northwestern Canada. Intern. Rev. Ges. Hydrobiol., **52**: 123–139.

HUTCHINSON, G. E. 1957. Treatise on limnology. Vol. I. Geography, physics and chemistry. Wiley, New York. 1015 p.

JUDAY, C., AND E. A. BIRGE. 1931. A second report on the phosphorus content of Wisconsin lake waters. Trans. Wisc. Acad. Sci., **26**: 353–382.

JUDAY, C., E. A. BIRGE, AND V. M. MELOCHE. 1938. Mineral content of the lake waters of northeastern Wisconsin. Ibid., **31**: 223–276.

KALFF, J. MS, 1965. Primary production rates and the effect of some environmental factors on algal photosynthesis in small arctic tundra ponds. Ph.D. Thesis. Indiana Univ., Bloomington, Indiana. 122 p.

1967a. Phytoplankton abundance and primary production rates in two arctic ponds. Ecology, **48**: 558–565.

1967b. Phytoplankton dynamics in an arctic lake. J. Fish. Res. Bd. Canada, **24**: 1861–1871.

LAMAR, W. L. 1966. Chemical character and sedimentation of the waters. *In* N. J. Wilimovsky and J. N. Wolfe [ed.] Environment of the Cape Thompson region, Alaska. U.S. Atomic Energy Comm., Oak Ridge. p. 133–148.

LIVINGSTONE, D. A. 1963a. Alaska, Yukon, Northwest Territories, and Greenland. *In* D. G. Frey [ed.] Limnology of North America. Univ. Wisc. Press, Madison, Wisc. p. 559–574.

1963b. Chemical composition of rivers and lakes. *In* Data of geochemistry. 6th ed. Chap G. U.S. Geol. Surv. Prof. Paper No. 4409. 64 p.

MacCarthy, G. R. 1952. Geothermal investigations on the Arctic Slope of Alaska. Trans. Am. Geophys. Union, **33**: 589–593.

Mackereth, F. J. H. 1963. Some methods of water analysis for limnologists. Freshwater Biol. Assoc. Sci. Publ. No. 21. 70 p.

Moyle, J. B. 1954. Some aspects of the chemistry of Minnesota surface waters as related to game and fish management. Minn. Dept. Conserv. Invest. Rept. No. 15. 36 p.

Payne, T. G., S. W. Dana, W. A. Fischer, S. T. Yuster, P. D. Krynine, R. H. Morris, E. H. Lathram, G. Gryc, and H. Tappan. 1951. Geology of the Arctic Slope of Alaska. U.S. Geol. Surv. Oil Gas Invest. Map 0M 126, U.S. Geol. Surv.

Prescott, G. W. 1963. Ecology of Alaskan freshwater algae. II. Introduction: General considerations. Trans. Am. Microscop. Soc., **82**: 83–98.

Rainwater, F. H., and L. L. Thatcher. 1960. Methods for collection and analysis of water samples. U.S. Geol. Surv. Water Supply Paper 1454. 301 p.

Rodhe, W. 1949. The ionic composition of lake waters. Verh. Inter. Ver. Limnol., **10**: 377–386.
1951. Minor constituents in lake waters. Ibid., **11**: 317–323.

Thomas, J. F. J. 1964. Surface water quality in major drainage basins and northern areas of Canada. J. Am. Water Works Assoc., **56**: 1173–1193.

United States Weather Bureau. 1964. Local climatological data for Barrow, Alaska. U.S. Dept. Com., Ashville, N.C.

Watson D. G., W. C. Hanson, J. J. Davis, and C. .F Cushing. 1966. Limnology of tundra ponds and Ogotoruk Ceek. *In* N. J. Wilimosky and J. N. Wolfe [ed.] Environment of the Cape Thompson Region, Alaska. U.S. Atomic Energy Comm., Oak Ridge. 1250 p.

Age, Growth, Food, and Yield of the White Sturgeon (*Acipenser transmontanus*) of the Fraser River, British Columbia[1,2]

By S. N. Semakula[3] and P. A. Larkin

Institute of Fisheries and Department of Zoology
University of British Columbia, Vancouver, B.C.

ABSTRACT

For white sturgeon taken incidentally in the salmon gillnet fishery in the Fraser River during the summer of 1962, pectoral fin ray sections indicated that over three-quarters were fish aged 9–16 years. Gillnets for salmon apparently select sturgeon over a size range between 30 and 60 inches. Back-calculation of size attained at previous ages indicated that after attaining a length close to 20 inches by age 5, the sturgeon grow about 2 inches per year to about age 25. Limited data from pectoral fin ray sections suggest that age at first spawning is from 11 to 22 years for males, and from 11 to 34 for females. Subsequent spawning is apparently at intervals of 4–9 years. Fraser River sturgeon are more piscivorous than has been recorded for white sturgeon and other sturgeon species elsewhere, about one-half of the stomachs containing fish, especially eulachons. The age distribution in the catch, though biased by selection, was used to estimate rates of natural and fishing mortality. The eumetric fishing curve suggests that present yield could be increased by a greater size at first capture, particularly if the natural mortality rate is as low as 0.05. The history of the sturgeon fishery suggest that sustainable yield could exceed 100,000 lb per year. The commercial landings in recent years average 30,000–40,000 lb. The sport fishery may take an additional 20,000–30,000 lb. Sustained yield in the circumstances of the present fishery could be 80,000 lb per year, about 25% more than the present catch. Some recommendations are made for management, stressing the importance of protection of an annual spawning population of 300–600 females.

INTRODUCTION

The present study attempts primarily to determine age distribution and growth rate in the Fraser River white sturgeon and relates the findings to the historical record of catch. Most of the material was obtained from 250 specimens caught incidentally by salmon fishermen in the lower part of the Fraser River, below Langley, during the period May 1–October 28, 1962. Twenty-two specimens below the legal size of 36 inches were gillnetted at Dewdney Slough, a backwater of the Fraser near Mission City.

METHODS OF AGEING AND BACK-CALCULATION OF GROWTH

Age determinations were made from transverse sections (Fig. 1) of thoroughly dried first pectoral fin rays. The sections were cut using a two-bladed

[1]Received for publication July 2, 1968.
[2]Based on a thesis submitted by S.N.S. in partial fulfillment of the requirements for the degree of Master of Science from the University of British Columbia, Vancouver, B.C.
[3]Present address: Fisheries Department, Entebbe, Uganda.

J. Fish. Res. Bd. Canada, 25(12): 2589–2602, 1968.
Printed in Canada.

saw and were between 0.3 and 0.5 mm thick. These were mounted in glycerine and examined with a binocular microscope. The validity of age determinations by this method is discussed by several authors including Cuerrier (1951), Probst and Cooper (1954), Roussow (1957), and Sunde (MS, 1961).

Sunde (1961) reported the progressive loss of annuli when pectoral fin ray sections are taken at increasing distances from the base. In the present study most sections taken $\frac{1}{4}$ inch from the base were difficult to read. This area coincides with the notched part of the ray, where the annuli tend to fuse. Sections taken $\frac{1}{2}$ inch from the base were, except in one instance, readable, whereas sections at $\frac{3}{4}$ inch showed some loss of annuli. Accordingly, sections were taken $\frac{1}{2}$ inch from the base of the fin ray and as close as $\frac{1}{4}$ inch for fish smaller than 20 inches.

For back-calculation of lengths at previous ages each fin ray section was mounted in glycerine and its image projected, and each annulus was marked at its point of sharp curvature on the ventral radial axis of the arrow-shaped section (Fig. 1). Two series of measurements of each image were taken: (1) the distances along the *curved* line from the centre of the fin ray to the various points of curvature of the annuli; and (2) the distances along the *straight* line from the centre of the fin ray to the point of curvature of the annulus at the periphery (Fig. 1). The relation between each of these fin ray measurements in arbitrary units (x) and fork lengths in inches (y) was apparently linear (Fig. 2 and 3) and the corresponding regression equations were:

$$y = 0.9 + 9.5x \text{ (curved line measurement)}$$

$$y = -3.1 + 10.2x \text{ (straight line measurement).}$$

In each case the correlation coefficient was approximately 0.9 and, there being no basis for choice of the one method, arbitrarily the curved measurement was used in constructing a nomograph for back-calculation. The nomograph procedure assumed that the intercept was constant and the slope variable.

Ages at spawning were assigned on the basis that zones of crowding of annuli reflect the diversion of energy to sex products, the last annulus of a crowded zone corresponding to the age of spawning (Roussow, 1957).

AGE DISTRIBUTION

The sturgeon ranged in age from 7 to 71 years and up to 91 inches in total length. Over three-quarters of the catch were fish from 9 to 16 years of age (Table I) probably reflecting, at least in some measure, a size selection by the limited range of meshes in the salmon gillnets. From February 1 to July 1, all mesh sizes are permitted but after May 1, when the sampling started, 8-inch mesh nylon nets are probably the most common used. During July, August, and early September, large mesh nets are usually replaced with smaller mesh in times of the week when fishing for sockeye salmon is permitted. The range of mesh sizes in common use is thus from 5 to 8 inches. The smaller mesh catches some sturgeon smaller than the legal limit of 36 inches but apparently

FIG. 1. Cross section of first pectoral fin ray, one-half inch from base, of Fraser River white sturgeon. The superimposed lines from the centre to the periphery are the lines along which radial measurements were made for back-calculations.

Semakula and Larkin — J. Fish. Res. Bd. Canada

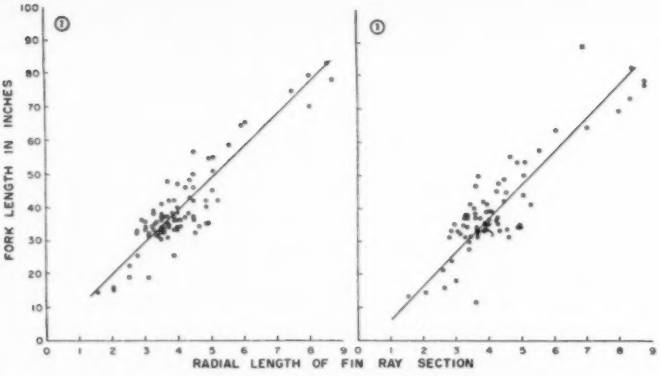


FIG. 2. Fork length in relation to length of the radius of the pectoral fin ray section as measured along a curved line (Fig. 1).

FIG. 3. Fork length in relation to length of the radius of the pectoral fin ray section as measured along a straight line (Fig. 1).

TABLE I. Age and length distribution of white sturgeon caught incidentally in the Fraser River gillnet fishery for salmon in 1962.

Age	No.	Approx length range (*inches*)	Age	No.	Approx length range (*inches*)
7	1	31	19	7	40–55
8	6	29–34	20	4	40–57
9	10	18.5–36	21	0	–
10	20	18–41	22	2	
11	31	30–51.5	23	3	40–62
12	22	31–48	24	2	
13	28	31–43	25	0	
14	14	30.5–51	26–30	1	
15	9	33–48.5	31–35	3	47–91
16	15	34–50	36–40	2	
17	2	32–36	41–50	1	
18	4	41–48	> 50	3	79–89

takes fish less than 30 inches only rarely. Large sturgeon may become "rolled" in the gillnets, regardless of the mesh size, but those over 60 inches, if they are available for capture by the salmon fishery, are probably too large for the gear. Hence, the age distribution in the catch is probably not an adequate indicator of age distribution in the population.

This selection may also account for the apparently disproportionate catch of young fish which seem to be relatively large for their age, and of old fish which are relatively small for their age. Thus the largest 10-year-old was larger than the smallest of age 23, and the largest 11-year-old was larger than

any other fish under 19 years old in the sample. The upper limit of the effectiveness of the gear is in the range of 50–60 inches.

GROWTH IN LENGTH AND WEIGHT

Growth, as indicated by length at age of capture (Fig. 4), is rapid up to the 10th year, then slows through the 11th–20th years, after which it is again rapid with an apparent decline after about age 35. This apparent pattern is probably related to the selective effect of the gillnet fishery in which the faster-growing younger fish and the slower-growing older fish are over-represented. The period of slower growth in the 10th–20th years is not as apparent in the growth curves based on back-calculated lengths (Fig. 5), the averaging procedure apparently combining the slower-growing older fish and the faster-growing younger fish to suggest a relatively uniform growth rate of about 2 inches a year from age 5 to age 18 for both sexes.

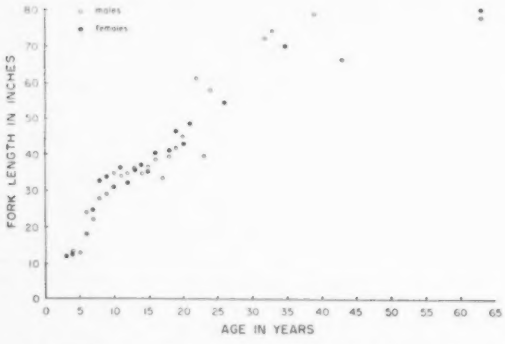


FIG. 4. Mean fork length at capture in relation to age at capture for male and female Fraser River white sturgeon.

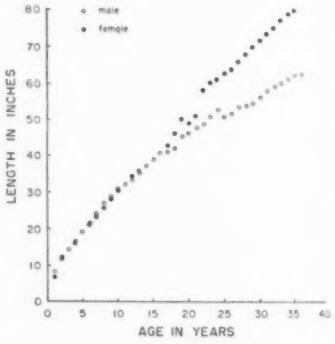


FIG. 5. Mean fork length in relation to age for males up to age 35 and females up to age 36 as indicated by back-calculated lengths.

There is some variability in the size attained at various ages by different year-classes. For example, males and females of the 1949 year-class were larger at all ages after the 5th year than those of the 1950 year-class (Table II). However, there was no suggestion of sequences of good or bad calendar years for growth, nor even the indication that all year-classes grew at comparable rates in the same years. Presumably the differences observed are largely fortuitous.

The relation between round weight in pounds (W) and fork length in inches (L) for all of the sturgeon taken in the Fraser commercial catch, together with small sturgeon taken in Dewdney Slough, is given by:

$$\log_e W = -8.73 + 3.13 \log_e L \text{ (males)}$$

$$\log_e W = -8.79 + 3.15 \log_e L \text{ (females).}$$

TABLE II. Fork lengths (inches) at various ages of male and female sturgeon of the 1949 and 1950 year-classes.

Age (*years*)	Females		Males	
	1949	1950	1949	1950
1	9	10	7	7
2	11	12	11	11
3	13	15	14	13
4	15	16	19	15
5	19	18	21	19
6	21	20	23	21
7	23	21	25	23
8	25	23	28	24
9	29	27	30	25
10	32	29	31	27
11	33	32	33	30
12	36	35	35	32
13	39	–	39	–

This series of observations (Fig. 6) was made chiefly on immature sturgeon of less than age 20 and the similarity of the length–weight relationships of the sexes may not be characteristic of mature specimens, particularly females. Older mature females develop substantial egg masses which may contribute to greater weight than that for males. For example, one specimen reported by a fisherman was 12 ft long, weighed 825 lb, and contained 200 lb of caviar.

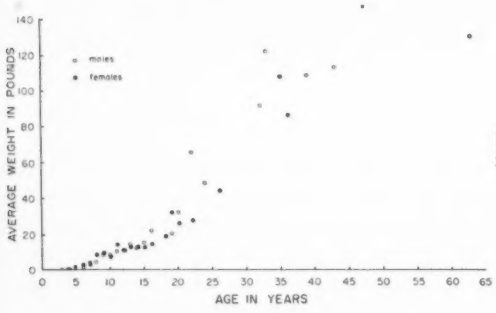


FIG. 6. Mean weight at capture in pounds in relation to age for Fraser River white sturgeon.

AGE AT FIRST SPAWNING AND INTERVALS BETWEEN SPAWNINGS

Sturgeon taken in the commercial catch were routinely examined for spawning condition, mature individuals being distinguishable by the degree of development and differentiation of the gonads. Fifteen of the male specimens were considered as mature, and of these 9, with ages ranging from 11 to 24 years, showed no growth history that suggested a previous spawning. This would suggest that age at first spawning is very variable, perhaps in part

related to the variability in growth rate. For the six males with a growth history that suggested previous spawnings, the first spawnings occurred after 3 years of slow growth sometime between age 11 and 22, the second spawnings (5 specimens) at age 16–17, and the third (3 specimens) at age 22–33. The interval between spawning averaged slightly less than 7 years, and ranged from 4 to 11 years.

The 17 mature females in the catch included 11 that had no apparent previous spawning and ranged in age from 11 to 22 years. The age at first spawning for the remaining six specimens ranged from age 26 to 34, with from 6 to 8 years of slow growth involved in the spawning check. Only one specimen clearly suggested a history of repeated spawnings with slow growth periods at ages 25–33, 36–40, and 46–49.

The limited data suggest that the age at first spawning varies considerably, but occurs at an earlier age in males. Additional spawning is also variable, occurring at intervals of 4–9 years, the males exhibiting 2–5 years and the females 3–8 years of slow growth prior to spawning. The observations of Magnin (1966a) suggest that these estimates may be correct for females but misleading for males. Magnin reports that males spawn every 2 years—more frequently than is suggested by the fin ray sections.

Compared with other species of sturgeons, those of the Fraser appear to reach maturity at a relatively advanced age. Roussow (1957) summarizes ages at first spawning reported for six species of sturgeon, all of which are at 14 years or less for males, and generally less than 20 years for females. *Acipenser fulvescens* is reported by Cuerrier (MS, 1949) as first spawning at age 14 for males and 23 for females, and by Magnin (1966b) at age 18–20 for males and 20–23 for females. Pycha (1956) suggests maturity of Columbia River white sturgeon at 11 or 12 years for females, much younger than for the Fraser River population.

FOOD

Stomach contents of fish taken in the period May–October 1962 suggest that sturgeon take a wide range of foods. In May, eulachons (*Thaleichthys pacificus*) were the main food item. Presumably at least some of the eulachons had died after spawning and had been scavenged from the bottom. According to local fishermen, it is common for sturgeon to contain eulachons in the spring months to the extent that the buyers of sturgeon deduct 2 lb from the weight of ungutted fish as a "eulachon allowance."

Fish occurred in 43 of a total of 88 stomachs which contained food. In addition to eulachons, they included, in order of abundance, sculpins (*Cottus* spp.), sticklebacks (*Gasterosteus aculeatus*), lampreys (Petromyzontidae), and, in one stomach, a young sturgeon. Fish were more commonly found in the stomachs of larger sturgeon. Fraser River sturgeon are apparently more piscivorous than has been recorded for *Acipenser* elsewhere (Harkness, 1923; Probst and Cooper, 1954).

Of the invertebrates taken as food, chironomid larvae were the most abundant and were recorded in 31 stomachs from sturgeon of all sizes. Crayfish (*Pacifastacus* sp.), stonefly larvae, and a few Ephemeroptera larvae, mysids, *Daphnia* spp., and freshwater copepods were other items recorded. Many stomachs contained plant material, some of it green and apparently from aquatic plants, but in several instances the plant debris was bark or pieces of wood. It seems likely that the plant material was largely taken incidentally.

MORTALITY RATES AND YIELD

Assuming constant recruitment, the age distribution in the commercial catch, though biased by the selection of the gillnets, may be used to give a first approximation of mortality rates of Fraser River sturgeon. Ignoring the age-groups on the left-hand limb of the catch curve as incompletely recruited, Fig. 7 suggests an instantaneous total mortality rate (F + M) of fish under

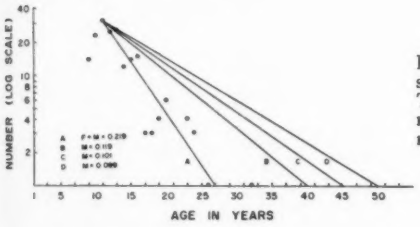


FIG. 7. Catch curve for Fraser River white sturgeon taken in the salmon fishery in 1962. The slope of line A gives the total instantaneous mortality rate; those of lines, B, C, and D, the natural mortalities with life expectancies respectively of 40, 45, and 50 years.

age 25 of 0.219, corresponding to an annual loss of 19.7% percent (line A). As the older age-groups are probably progressively less well represented in the catch because of the selectivity of the gear, this is almost certainly too high as an estimate of total mortality.

Expressing natural mortality in the conventional way as

$$N_{t_2} = N_{t_1} e^{-M(t_2 - t_1)}$$

then the survival of one fish at t_2 from a cohort of 31 at age 11 may be associated with various rates of natural mortality. With a reduction of this magnitude by age 40 the natural mortality rate (M) would be 0.119 (line B, Fig. 7); by age 45, M = 0.101 (line C); by age 50, M = 0.089 (line C). Fish of age 50 and over, even though poorly represented in the catch, are nevertheless present, and from what is known of sturgeon, life expectancies of 80 years are not uncommon in virgin stocks. With M = 0.089 the proportion of 11-year-olds surviving to age 80 is only 0.22%. Accordingly, all of these estimates of natural mortality are probably too high. A reduction of a cohort of 31 at age 11 to a single individual at age 80 corresponds to a natural mortality rate of M = 0.05, and the proportion of 11-year-olds surviving to age 80 is 3.2%. For M = 0.05 the implied fishing mortality rate (F) is 0.169 because the total mortality rate (F + M) is 0.219.

All of these estimates are, of course, only very approximate and are biased by the inadequate representation of fish older than age 25 that are largely unavailable to the commercial salmon fishery. Nevertheless, they may be used as a basis for a projection of what yield might be from the *present* type of fishery. To estimate yield per recruitment, Ricker-type yield tables were constructed using instantaneous growth rates at various ages (g) based on the back-calculated data of Fig. 5. Fish were assumed to be beyond catchable size after age 35. Table III is an example for M = 0.089, F = .05. The yields

TABLE III. Example of calculation of yield for Fraser River sturgeon in the circumstances of the present fishery. M = 0.089; F = 0.05 from age 10 onward.

Age	Avg L	Avg W	g	g-(F+M)	Wt change factor	Wt of stock	Avg wt of stock	Yield per recruitment of 1000 lb
1	9.0	.154						
2	12.1	.390						
3	14.2	.650						
4	17.0	1.24				1000		
5	17.0	1.77	.44	+.351	1.420	1420	1210	
6	21.7	2.46	.33	+.241	1.273	1808	1614	
7	24.1	3.36	.31	+.221	1.247	2254	2031	
8	26.0	4.10	.20	+.111	1.117	2518	2386	
9	28.3	5.70	.33	+.241	1.273	3205	2862	
10	30.6	7.25	.24	+.101	1.106	3545	3375	168.75
11	33.9	10.1	.33	+.191	1.210	4290	3918	195.90
12	35.0	11.1	.10	−.039	0.962	4127	4209	210.45
13	37.0	13.2	.17	+.031	1.031	4255	4191	209.55
14	39.0	15.6	.17	+.031	1.031	4387	4321	216.05
15	40.8	18.0	.14	+.001	1.001	4391	4389	219.45
16	42.9	21.2	.16	+.021	1.021	4484	4438	221.90
17	44.8	24.2	.14	+.001	1.001	4488	4486	224.30
18	46.5	27.1	.11	−.029	0.971	4358	4423	221.15
19	48.0	30.0	.10	−.039	0.962	4193	4276	213.80
20	50.0	43.1	.13	−.009	0.991	4155	4174	208.70
21	51.6	37.8	.10	−.039	0.962	3997	4076	203.80
22	53.2	41.7	.10	−.039	0.962	3845	3921	196.05
23	54.9	46.1	.10	−.039	0.962	3699	3772	188.60
24	54.9	50.4	.09	−.049	0.952	3522	3611	180.55
25	58.2	55.2	.09	−.049	0.952	3352	3437	171.85
26	60.0	61.0	.11	−.029	0.971	3255	3304	165.20
27	61.5	65.4	.07	−.069	0.933	3037	3146	157.30
28	63.0	70.8	.08	−.059	0.943	2864	2951	147.55
29	64.2	75.2	.06	−.079	0.924	2646	2755	137.75
30	65.5	79.9	.06	−.079	0.924	2445	2546	127.30
31	66.7	84.8	.06	−.079	0.924	2259	2352	117.60
32	68.0	90.1	.06	−.079	0.924	2088	2174	108.70
33	69.2	95.1	.06	−.079	0.924	1929	2009	100.45
34	70.6	101.0	.05	−.089	0.915	1765	1847	92.35
35	71.7	106.0	.05	−.089	0.915	1615	1690	84.50
			.05	−.089	0.915	1478	1547	77.35
								4566.90

given in Fig. 8 are those corresponding to 1000 lb of recruitment at age 4 with the value of M = 0.089. Over a wide range of fishing mortality rate, increased equilibrium yield would be obtained with a slightly older age of entry than the 5–10 years in the present fishery, but the potential gains are not great. However, if natural mortality rate is lower than 0.089, the potential gain from reduced rates of fishing or older ages of entry is more substantial. For example, with M = 0.05 and age of entry 5 years, the yield at F = 0.07 is about twice as great as that at F = 0.20 (Fig. 9). If natural mortality rates of sturgeon are 0.05 or lower, yield could be considerably enhanced by reducing fishing mortality.

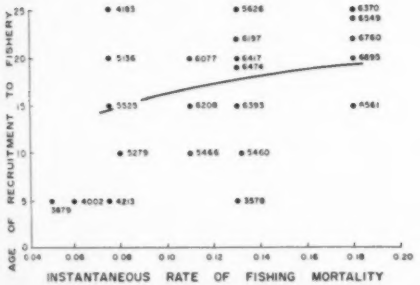


FIG. 8. Yields in pounds per thousand pounds of recruitment of 4-year-old sturgeon (numbers on face of figure) for various ages of recruitment at various instantaneous rates of fishing mortality when natural mortality rate (M) is 0.089. The position of the eumetric fishing curve was approximated by estimating for each rate of fishing, the maximum point on a parabola fitted to values on both sides of the maximum.

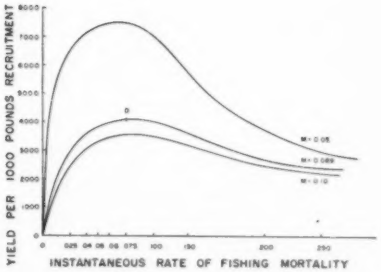


FIG. 9. Yields in pounds per thousand pounds of recruitment at different rates of fishing and three natural mortality rates. Age of entry 5 years. Maximum age of capture 35 years.

HISTORY OF THE STURGEON FISHERY

The sturgeon fishery of the Fraser appears to exhibit the properties of fish stocks described by Ricker (1963) which, because of great longevity, may respond to intense initial exploitation with dramatic declines in catches.

Late in the 19th century fisheries for sturgeon were substantial in many parts of the continent, and in British Columbia where almost all of the catch came from the Fraser River, the fishery reached a peak just before the turn of the century (Table IV). Prior to 1880 there was a small subsistence fishery by the native Indians, and Lord (1866) mentioned trade in a crude kind of isinglass (a form of gelatin obtained from the swim bladder lining) between the Indians and the Hudson's Bay Company. This trade ceased by 1886, but with the development of the salmon fisheries, there was a growing incidental catch of sturgeon in salmon nets. The annual reports of the regional fisheries inspector after 1880 contained data and frequently remarks on the sturgeon fishery. Local markets for caviar and sturgeon flesh gradually increased and

TABLE IV. Catch statistics of the sturgeon fishery of the Fraser River from 1880 to 1963. Prior to 1906 catches are for all of British Columbia, but catches in areas other than the Fraser were trivial. (Data for the period prior to 1918 from Annual Reports of the Canada Department of Marine and Fisheries; from 1918 on, from files of the Department of Fisheries of Canada, Pacific Area, Vancouver, B.C.).

Year	Catch in lb	Year	Catch in lb	Year	Catch in lb	Year	Catch in lb
1880	80,000	1901	65,000[a]	1922	32,200	1943	17,600
1881	70,271	1902	33,500	1923	57,400	1944	26,100
1882	79,700	1903	30,000	1924	30,600	1945	31,000
1883	399,393	1904	35,000	1925	27,400	1946	18,200
1884	352,900	1905	20,000	1926	27,500	1947	46,000
1885	354,500[b]	1906	25,000	1927	35,900	1948	25,000
1886	114,900	1907	100,000	1928	27,900	1949	42,100
1887	249,000[c]	1908	180,000	1929	31,400	1950	36,900
1888	215,500	1909	500,000	1930	27,700	1951	25,700
1889	318,600	1910	550,000	1931	25,200	1952	39,200
1890	396,000	1911	516,800	1932	20,200	1952	54,400
1891	324,500	1912	505,100	1933	36,700	1954	27,500
1892	520,500	1913	109,000	1934	21,200	1955	35,600
1893	330,000	1914	114,900	1935	43,600	1956	34,300
1894	592,106[d]	1915	81,100	1936	14,000	1957	30,100
1895	375,000	1916	73,000	1937	8,200	1958	48,800
1896	380,500[e]	1917	44,500	1938	18,700	1959	38,800
1897	1,137,696	1918	10,300	1939	15,600	1960	33,300
1898	750,000[f]	1919	22,200	1940	15,100	1961	35,900
1898	278,650	1920	14,300	1941	22,100	1962	29,100
1900	105,000[g]	1921	19,700	1942	9,800	1963	29,100

[a]"Practically extinct commercially."
[b]Said to be for "home consumption."
[c]Said to be mostly taken in salmon nets.
[d]Increasing demand and expanding market to east.
[e]Reference to substantial "poaching" by local settlers and natives.
[f]Licences 164.
[g]Licenses 23.

by 1888 were the subject of remark in the annual report of the regional fisheries inspector. By 1894 export to eastern markets was underway and by 1896 concern was expressed about "poaching" in lakes and sloughs and the difficulties of protecting a resource of growing importance. The peak catches in 1897 of over a million pounds and in 1898 of three-quarters of a million pounds, were followed by a sharp decline to 65,000 lb in 1901. There was a corresponding reduction in licensed fishermen and a verdict by the fisheries inspector that the sturgeon fishery was "practically extinct commercially."

It was realized that slow growth of sturgeon might be a factor in the rapid decline in catches. In 1907 catches began to increase, reaching one-half a million pounds in each of the 4 years 1909–12. In 1911 regulations allowed only gillnets and drift nets of 12-inch mesh; a closed season was declared from November 15 to March 25. Fishermen were apparently permitted to retain

any fish over 8 inches in length or 3 lb in weight (either a misprint or a misunderstanding; Commission of Conservation, Canada, 1911, page 59). In 1915 the size limit became 36 inches. Catches declined despite the regulations and since 1918 commercial catches have ranged from 10,000 to 50,000 lb annually. A diffuse sports fishery, some of the catches of which are included in the commercial landings, might take an additional 20,000 to 30,000 lb annually.

YIELD ESTIMATES

There were thus two distinct periods of harvesting in the sturgeon fishery, the first and largest from 1880 to 1900, the second from 1907 to 1917. Taken together, these two harvests provide an opportunity for estimating the stock size and for testing the validity of the estimate.

It is first necessary to estimate the weight of a stable and unfished stock per 1000 lb of recruitment. This may be done by extending a table such as Table III to age 85 and assuming various growth and mortality rates, and no fishing mortality. It may be supposed that an initial fishery would concentrate on the larger mature fish, say those over age 25, so that recruitment may be expressed per 1000 lb of 25-year-olds. It may be assumed that the natural mortality rate (M) is between 0.089 (probably too high) and 0.05 (which seems reasonable). If it is assumed that growth rate after age 35 is at $g = 0.05$, then a sturgeon weighing roughly 100 lb at age 35 would at age 85 be $100\ e^{.05(50)} = 1220$ lb which is within the recorded weight of sturgeon (Clemens and Wilby, 1961). With this growth rate the increments in weight would exactly balance the losses from natural mortality at a rate of $M = 0.05$, so that the biomass of a cohort of sturgeon would remain constant after age 35! Using the two estimates of natural mortality rate, the weight of a stable and unfished stock of sturgeon per 1000 lb of recruitment of 25-year-olds is estimated as 27,600 ($M = 0.089$) and 65,000 lb ($M = 0.05$).

During the period from 1880 to 1900 removals by the fishery totalled 7,315,000 lb, which may be taken as virtually the whole of the accumulated stock of fish over age 25. During the same period recruitment at age 25 added each year 1000 lb per unit of recruitment. Assuming that these additions were exploited heavily and contributed their full 1000 lb per unit to the catch, and that recruitment was not reduced because of the reduction in stock size, we may set X = the number of units of recruitment per year, and write, for $M = 0.089$, $7{,}315{,}000 = 27{,}600 \times X + 21 \times 1000\ X$. The solution suggests that at a natural mortality rate of 0.089, the virgin stock would be the resultant of a long-term constant recruitment of about 150 units per year, and the virgin stock would be thus 150 (27,600) or 4,140,00 lb of sturgeon aged 25 and over.

For $M = 0.05$, the long-term constant recruitment is estimated as about 85 units per year, each associated with 65,000 lb of stock, or a stock of 5,525,000 lb of sturgeon aged 25 and over.

The period from 1901 to 1906 provided some respite, removals totalling 208,500 lb. With $M = 0.089$, recruitment would have added $6 \times 150 \times 1000$ or 900,000 lb to the stock for a net gain of about 700,000 lb (this calculation

also assuming that the reduction in stock did not reduce recruitment). From 1907 to 1917 there was added 11 × 150 × 1000 or 1,650,000 lb which, it may be assumed, was taken immediately upon recruitment. The net gain from 1901 to 1906 and the recruitment additions from 1907 to 1917 suggest an available catch from 1907 to 1917 of 2,300,000 lb, which is in good agreement with the recorded catch of 2,774,400 lb. Alternatively, for M = 0.05, recruitment would have added 6 × 85 × 1000 or 510,000 lb for a gain of 300,000 lb from 1901 to 1906, and a further 11 × 85 × 1000 or 935,000 lb from 1907 to 1917, for a total increment of 1,235,000 lb, which is considerably less than the recorded catch of 2,774,400 lb.

The foregoing analysis confirms that the earlier sturgeon fishery exhausted the virgin stock and then after a brief intermission removed a small accumulation. The analysis does not indicate something else that was probably going on, particularly in the period from 1907 to 1917 — the removals of smaller sturgeon under 25 years of age by the salmon fishery which blossomed just before the turn of the century and was highly effective. It is possible that by 1917 there were very few sturgeon over age 15.

Reconsidering now the present situation with an annual input of 85–150 units, each of 1000 lb of 25-year-old recruits, the maximum sustained yield is obviously between 85,000 and 150,000 lb, age 25 corresponding closely to the critical age when gains from growth are the equivalent of losses from natural mortality (Table III). At rates of fishing less than the theoretical maximum, yields are more than two-thirds of the maximum. Figure 8, for example, provides the relation between yield per unit of recruitment and age of entry at various rates of fishing. In the absence of a fishery, each 1000 lb of recruitment at age 4 corresponds to 7500 lb of recruitment at age 25. Thus, 150 units each of 1000 lb of 25-year-old recruits are the equivalent of 20 units of 4-year-old recruits. On this basis, then, it is implied that sustained yield in the present fishery (age of entry 10 years, F = 0.13) could be 20 × 5460 or 109,200 lb per year, more than twice the current yield of about 30,000–40,000 lb. A similar calculation assuming M = 0.05 suggests a potential yield of 98,000 lb in the circumstances of the present fishery.

If the present rate of fishing is over-estimated, then the potential yield would be scaled downward to perhaps as low as 4000 lb per unit of recruitment, for a total of 80,000 lb per year. Additionally, it is possible that the present catch may be substantially larger than is reported in commercial catch statistics. The sport fishery for sturgeon along the Fraser might take as much as 20,000–30,000 lb per year, bringing the total to 50,000–70,000 lb per year. Making these kinds of adjustments, the analysis of Fig. 8 could be reconciled with the historical catches and would suggest a maximum sustainable yield of perhaps 80,000 lb per year, about 25% more than the possible current combined sport and commercial catch of 60,000 lb.

In the foregoing analysis the assumption that recruitment is independent of stock size may be a dubious assumption considering the very small numbers of fish involved. For example, if the stock comprises the resultant of 20 units

(20,000 lb) of recruitment of 4-year-olds, there are about 16,100 4-year-olds (which weigh about 1.24 lb each). With a natural mortality rate of 0.089 and a total mortality rate (F+M) of 0.219 after age 11, the number of fish of age 25 is only 502. Assuming no fishery on fish over age 25, the total stock of fish age 25 and over is only 5900. Assuming M = 0.05 throughout, there are 85 units of 25-year-old recruits, and their equivalent is 4050 4-year-olds; and with the fishery after age 11, there are 165 fish of age 25 and a total stock over 25 of 3400. If females spawn only every 5 years and the sex ratio is one to one, then the average spawning population comprises about 300–600 females. Plainly, with even a modest fishery on the old large females, it might be expected that recruitment would be affected.

The foregoing estimates are highly speculative but contain an interesting corollary. As the fishery in the past 40 years has been mostly incidental and older fish are therefore largely unexploited, it seems likely that there is a small accumulation of older fish that might temporarily augment a modest fishery. In the circumstances, a trial fishery for 2 or 3 years, specifically for sturgeon over 48 inches long and taking 100,000 lb per year in waters of the Fraser River downstream from Hope, would seem to be warranted and could provide information on which to base a further stock assessment.

OTHER MANAGEMENT CONSIDERATIONS

Little is known of the life history of the Fraser River white sturgeon. Periodically, large specimens are reported along the length of the river downstream from the vicinity of the lower end of the Fraser canyon, and in the large sloughs and tributary lakes of the river below Hope. The fishery should be prosecuted throughout the area because it seems possible that the larger and older fish may in part be found away from the main stem of the river. It is possible that spawning is concentrated in the lower part of the Fraser canyon as it is likely that sturgeon spawn in relatively fast water. If a fishery should indicate that the spawning sturgeon would be too vulnerable to capture in such circumstances, appropriate closures could be instituted. It is indicated in some preliminary studies by Bajkov (1951) on Columbia River white sturgeon that there are seasonal migrations (upstream 100 miles in the fall, downstream to the mouth in the spring). If there are similar migrations on the Fraser, there could be management implications and a tagging study would be a useful adjunct to an experimental fishery.

ACKNOWLEDGMENTS

The Westminster Fishing Company Limited were particularly helpful in providing specimens of sturgeon for examination. The late Dr W. A. Clemens stimulated the study in its early stages. Drs Norman J. Wilimovsky and T. G. Northcote assisted in the interpretation of the data. Drs W. E. Ricker and K. S. Ketchen, Fisheries Research Board of Canada, Nanaimo, B.C., provided very useful criticism of the yield calculations. L. Steigenberger

and I. Todd made many useful suggestions. The senior author was supported by a Commonwealth Scholarship awarded by the Canadian Universities Foundation.

REFERENCES

BAJKOV, A. D. 1951. Migration of the white sturgeon (*Acipenser transmontanus*) in the Columbia River. Oregon Fish. Comm. Res. Briefs, **3**(2): 8–21.

CANADA DEPARTMENT OF MARINE AND FISHERIES. Annual reports 1880 to 1919.

CLEMENS, W. A., AND G. V. WILBY. 1961. Fishes of the Pacific Coast of Canada. Bull. Fish. Res. Bd. Canada, No. 168. 443 p.

COMMISSION OF CONSERVATION, CANADA. 1911. Lands, fisheries and game, and minerals. 519 p.

CUERRIER, J. P. MS, 1949. Observations sur l'esturgeon de lac (*Acipenser fulvescens* Raf.) dans la région du lac Saint-Pierre au cours de la période du frai. These. Université de Montréal, Montréal, Qué.

1951. The use of pectoral fin rays for determining age of sturgeon and other species of fish. Canadian Fish-Culturist, No. 11. p. 10–18.

HARKNESS, W. J. K. 1923. The rate of growth and food of the lake sturgeon (*Acipenser rubicundus* Le Sueur). Univ. Toronto Studies, Biol. Ser., Publ. Ont. Fish. Res. Lab., No. 18. p. 15–42.

LORD, J. K. 1866. The naturalist in Vancouver Island and British Columbia. Richard Bentley, London 1. 368 p.

MAGNIN, ETIENNE. 1966a. Recherches sur les cycles de reproduction des esturgeons *Acipenser fulvescens* Raf. de la rivière Nottaway tributaire de la baie James. Canadian J. Zool., **44**(2): 257–263.

1966b. Quelques données biologiques sur la reproduction des esturgeons *Acipenser fulvescens* Raf. de la rivière Nottaway, tributaire de la baie James. Ibid., **44**(2): 257–263.

PROBST, R. T., AND E. L. COOPER. 1954. Age, growth and production of the lake sturgeon (*Acipenser fulvescens*) in the lake Winnebago region, Wisconsin. Trans. Am. Fish. Soc., **84**: 207–227.

PYCHA, R. L. 1956. Progress report on white sturgeon studies. Calif. Fish Game, **42**(1): 23–35.

RICKER, W. E. 1963. Big effects from small causes: two examples from fish population dynamics. J. Fish. Res. Bd. Canada, **20**(2): 257–264.

ROUSSOW, GEORGE. 1957. Some considerations concerning sturgeon spawning periodicity. Ibid., **14**(4): 553–572.

SUNDE, L. A. MS, 1961. Growth and reproduction of the lake sturgeon (*Acipenser fulvescens* Rafinesque) of the Nelson River in Manitoba. M.Sc., Thesis. Dept. Zool., University of British Columbia, Vancouver, B.C.

Respiration of the Winnipeg Goldeye (*Hiodon alosoides*)[1]

By J. S. Hart[2]

Department of Zoology
University of Toronto, Toronto, Ont.

ABSTRACT

The respiratory metabolism of groups of goldeye was measured during rest and sustained swimming activity at 5, 10, and 15 C under conditions of continuous reduction in oxygen by the metabolism of the fish. The oxygen consumption fell progressively during swimming at all temperatures indicating dependence of metabolism on oxygen supply at all pO_2 levels. During rest the oxygen consumption was relatively independent of pO_2 until certain critical levels were reached. Respiration became markedly limited by CO_2 in the medium when the pCO_2 exceeded 50 mm Hg. It is apparent that survival possibilities of goldeye would be limited by pO_2 and pCO_2 between 20–40 mm Hg during the winter.

INTRODUCTION

Stagnation conditions under ice in the lakes and ponds along the Saskatchewan River have been reported to be detrimental to the survival of Winnipeg goldeye (Sprules, MS, 1947). To provide a basis for understanding of overwintering mortality in nature, a physiological study of the limiting conditions for performance and survival of goldeye in respect to oxygen supply and carbon dioxide accumulation was carried out in 1947. Oxygen consumption was measured at various temperatures during both rest and sustained swimming (maximal cruising speed), the oxygen concentration being progressively reduced by the metabolism of the fish. The effect of CO_2 accumulation was studied by measuring the ability of the fish to extract oxygen from water containing different amounts of CO_2. Although the methods used have since been refined considerably, the material is being published because it is the only basic information on a valuable species.

METHODS

Goldeye used were caught by seine in the Saskatchewan River near The Pas, Manitoba, from October 7–30, and had an average weight of 9.4 g. After capture, they were kept in large acclimation tanks with aeration but no running water for at least 3 weeks at 5, 10, and 15 C before tests were started. All subsequent tests were carried out at these acclimation temperatures.

Three types of tests were carried out. In the first, groups of 10–25 fish were placed in a tank containing about 25 liters of water, and after sealing off from outside air, samples were taken at intervals of 0.5 or 1 hr for de-

[1]Received for publication April 25, 1968.
[2]Present address: Division of Biology, National Research Council, Ottawa, Ont.

J. Fish. Res. Bd. Canada, 25(12): 2603–2608, 1968.
Printed in Canada.

termination of oxygen uptake. The tests began in late afternoon and evening and continued for 8–12 hr when nearly all the oxygen had been removed from the water. The fish were disturbed as little as possible in these tests. The free CO_2 content of the water was determined at the end of each test.

In the second series of tests, the oxygen consumption was measured in groups of 10–25 fish swimming in a rotating annular tank containing about 5 liters of water and covered by a waxed board to eliminate any significant gas diffusion from the atmosphere (as described by Fry and Hart, 1948, fig. 1). To stimulate maximal sustained effort, the rate of rotation was slightly faster than that which the fish could maintain. The speed was gradually reduced as the swimming speed declined with reduction in oxygen in the water. For determination of oxygen consumption, 100-ml samples were withdrawn for oxygen content analysis every 0.5 hr until the oxygen was depleted, after about 2–4 hr.

During some of the measurements of resting oxygen consumption it was found necessary to correct for the oxygen uptake of the medium itself, which at times, was a substantial portion of the total uptake (0.11 ml/hr at 5 C, 0.21 ml/hr at 10 C, and 0.37 ml/hr at 15 C per 25 liters of water). This uptake by the water was negligible in tests during activity.

In the third series of tests, the respiratory sensitivity was determined by measuring the ability of goldeye to extract oxygen in the presence of various amounts of CO_2, at 5 and 15 C after sealing individual fish in pint or quart bottles and measuring the oxygen and CO_2 remaining at the moment of death. The initial as well as the final oxygen and CO_2 values after death were determined in all tests.

The oxygen content of the water was determined by the permanganate modification of the Winkler method, using 100-ml samples (American Public Health Association, 1946) and carbon dioxide content was by titration against sodium hydroxide with phenolphthalein indicator. The contents were converted to tensions from the temperature and pressure at the time of the tests and verified by Krogh's method (Krogh, 1908) for gas microanalysis.

RESULTS AND DISCUSSION

Resting Oxygen Consumption

Oxygen consumption rates at rest conform with the term "routine oxygen uptake" (Fry, 1957, who used the author's data as an illustration) rather than standard rates since no attempt was made to estimate the metabolism at zero activity. Furthermore, the presence of groups rather than single fish in the tests may have been somewhat stimulatory.

In spite of pooled samples with groups of fish, the resting rates of oxygen consumption at each acclimation temperature varied notably (Fig. 1) owing probably to sampling errors resulting from inadequate mixing in the large volume chamber. However, the effect of temperature on the resting oxygen consumption is clear and gives a Q_{10} of approximately 2.9 between 5 and 15 C at the highest pO_2 levels.

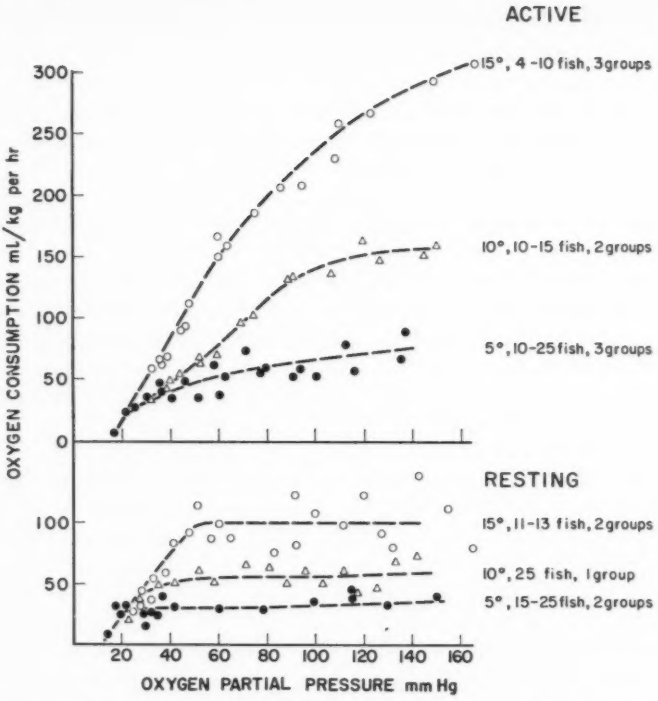


FIG. 1. Oxygen consumption of resting and active goldeye acclimated and tested at three different temperatures (C). Part of the data have been previously published by Fry (1957, fig. 1).

As the pO_2 declined, oxygen uptake was independent of pO_2 until a critical level was reached below which it abruptly declined. The critical levels, obtained by inspection declined with temperature (Table I). The fish became distressed at these low pO_2 levels and frequently lost equilibrium.

TABLE I. Performance characteristics of goldeye estimated from Fig. 1.

Temp (C)	Oxygen uptake at air saturation (*ml/kg per hr*)		Scope for activity index[a] (*ml/kg per hr*)			Critical pO_2 (*mm Hg*)
	Resting	Active	Air sat.	80 mm Hg	40 mm Hg	
15	100	300	200	100	0	50
10	60	160	100	55	0	35
5	35	75	40	25	10	25

[a]Scope for activity index is less than true scope by the elevation of resting uptake above minimal levels and by the reduction of active uptake below maximal levels.

Active Oxygen Consumption and Respiratory Dependence

Unlike the resting oxygen consumption, active rates (Fig. 1, top section) declined progressively with falling pO_2 at the three temperatures, as appears to be typical of fish. The effect of temperature on the respiratory dependence curves as well as on the oxygen consumption at air saturation was marked in this species, as in the speckled trout (Graham, 1949). Under declining oxygen pressure the oxygen consumption differed at the different temperatures except at very low pO_2 levels in the neighborhood of 20 mm Hg and below as also found in other species (e.g. Beamish, 1964).

A comparison of the upper and lower sections of Fig. 1 indicates that the declining portion of the respiratory dependence curve for resting fish at each temperature approximates that seen in the active fish. Unlike that observed in brook trout (Beamish, 1964) the point of inflection of the curves for resting fish occurs on the declining portion for active fish. The point of inflection thus appears to be identical to the level of no excess activity.[3]

Although swimming speeds were not measured it was noted that a gradual decline occurred as the oxygen became depleted. The increased activity and increased oxygen consumption of resting fish, noted by earlier workers in the range of respiratory dependence (Fry, 1957), was usually masked by the grouping of fish in these tests. Nevertheless an indication of "oxykinesis" is given by Fry (1957, fig. 1) for the goldeye. Stimulation of activity by hypoxia in resting fish may partly account for the congruence of the curves for resting and active fish in the range of respiratory dependence.

It must be emphasized that critical levels and levels of no excess activity estimated for this species have no absolute significance for comparison with other species in which standard oxygen consumption was measured. The data are useful for intraspecific comparisons at different temperatures but the estimated levels were too high at any given temperature owing to the presence of spontaneous activity. In the goldeye, regardless of activity the oxygen consumption falls to zero at approximately 15 mm Hg pO_2.

Scope for Activity Index

The scope for activity (Fry, 1947), defined as the difference between the active and standard rates of oxygen consumption, is referred to as an index since routine rather than standard rates were measured. However, the index of the scope at air saturation is of value for comparing the effect of temperature on performance (Table I). In the goldeye, there was a fourfold decrease in scope from 15 to 5 C. With decline in pO_2, the scope for activity was reduced to approximately 50% of that at air saturation at a pO_2 of 80 mm Hg at all temperatures, and to near zero at 40 mm Hg. By definition, the scope for activity falls to zero at the level of no excess activity. This level is only slightly higher than the asphyxial level shown by Shepard (1955) and Basu (1959).

[3]The pO_2 level at which the rate of oxygen uptake of active fish is reduced to no more than the requirement for standard metabolism (Fry, 1947).

Respiratory Sensitivity

The residual oxygen level in the goldeye is little influenced by CO_2 until the pCO_2 level exceeds 40 mm Hg (Fig. 2). No effect of temperature on the respiratory sensitivity was noted. The goldeye is moderately sensitive to CO_2 in comparison to a series of species examined by Hart (1945).

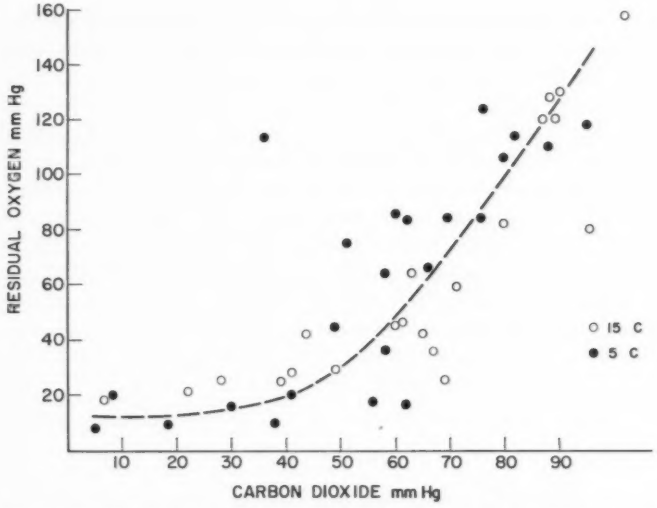


Fig. 2 Residual oxygen and carbon dioxide in water at asphyxiation for goldeye at 5 and 15 C.

The residual level has been shown by Basu (1959) to be the least sensitive of all methods of measuring respiratory sensitivity to CO_2. From the species examined by him it was apparent that the pO_2 levels of no excess activity were affected at less than half the pCO_2 levels corresponding to the residual oxygen levels. If the same estimate applies for the goldeye it might be concluded that the level of no excess activity would be raised by any level of CO_2 exceeding about 20 mm Hg.

Estimated Ability to Survive Stagnation at 0 C

Many factors besides oxygen limitation and excess CO_2 contribute to the hazards of life under ice during winter. Estimates of survival capabilities from physiological data can therefore give only the most favorable picture, applicable only to the factors under consideration. An additional uncertainty in these estimates is the extrapolation required for conditions at 0 C from data obtained at higher temperatures.

The goldeye does not appear to possess any unique features which would render it particularly suited to stagnation conditions in nature, unless it be

an exceptional ability to acclimatize to low oxygen levels — a capability not examined in this study. Extrapolation of data obtained at various levels of pO_2 in acute tests, indicated that oxygen consumption falls to zero between 15 and 20 mm Hg at all temperatures with pCO_2 below 10 mm Hg. This can be therefore considered as a minimal level below which survival seems unlikely. This conclusion is supported by the observed distress and loss of equilibrium noted in tests at very low pO_2 pressures.

At pressures of pO_2 between 20–40 mm Hg at 5–15 C the scope for activity index falls to near zero, signifying insufficient oxygen for the maintenance of normal activity. However, the fish would require less oxygen at 0 C and the level of no excess activity would be further reduced. Extrapolation of the log resting oxygen consumption between 15 and 5 C to 0 C indicates that goldeye would consume approximately 25 ml/kg per hr at 0 C. With this low oxygen consumption the level of no excess activity would correspond to about 20 mm Hg, but it would be raised considerably if the CO_2 in the water exceeded 20–40 mm Hg, as discussed above. Considering all the uncertainties of these estimates and extrapolations it may be concluded that levels of CO_2 exceeding 20–40 mm Hg and pO_2 levels below 20–40 mm Hg are likely to seriously limit the possibilities for survival of goldeye during the winter.

ACKNOWLEDGMENTS

These studies were carried out in 1947 under contract with Fisheries Research Board of Canada.

REFERENCES

AMERICAN PUBLIC HEALTH ASSOCIATION. 1946. Standard methods for the examination of water and sewage. 9th ed. Lancaster Press.

BASU, S. P. 1959. Active respiration of fish in relation to ambient concentrations of oxygen and carbon dioxide. J. Fish. Res. Bd. Canada, **16**(2): 175–212.

BEAMISH, F. W. H. 1964. Respiration of fishes with special emphasis on standard oxygen consumption. Canadian J. Zool., **42**: 355–366.

FRY, F. E. J. 1947. Effects of the environment on animal activity. Univ. Toronto Studies, Biol. Ser., No. 55, Publ. Ont. Fish. Res. Lab., No. 68. p. 1–62.
1957. The aquatic respiration of fish. *In* M. Brown [ed.] The physiology of fishes. Vol. I. Academic Press, Inc., New York. p. 1–63.

FRY, F. E. J., AND HART, J. S. 1948. The relation between temperature and oxygen consumption of goldfish. Biol. Bull., **94**: 66–77.

HART, J. S. 1945. The circulation and respiratory tolerance of some Florida freshwater fishes. Proc. Florida Acad. Sci., **7**: 221–246.

GRAHAM, J. M. 1949. Some effects of temperature and oxygen pressure on the metabolism and activity of the speckled trout, *Salvelinus fontinalis*. Canadian J. Res. (D), **27**: 270–288.

KROGH, A. 1908. On microanalysis of gases. Skand. Arch. Physiol., **20**: 279–288.

SHEPPARD, M. P. 1955. Resistance and tolerance of young speckled trout (*Salvelinus fontinalis*) to oxygen lack, with special reference to low oxygen acclimation. J. Fish. Res. Bd. Canada, **12**(3): 387–446.

SPRULES, W. M. MS, 1947. A report of water analyses made in the Summerberry marsh region between March 3 and 7, 1947. Fish. Res. Bd. Canada, MS Rept. Central Lab. 1947.

Stratification and Mixing in Coastal Waters of the Western Gulf of Maine during Summer[1,2]

By Edward M. Hulburt

Woods Hole Oceanographic Institution
Woods Hole, Massachusetts, USA

ABSTRACT

In the summers of 1966 and 1967, very low surface temperatures, about 11 C, and weakly stratified water occurred along the western coast of the Gulf of Maine at Cape Nedick, in the Sheepscot River, and off Vinalhaven Island at the mouth of Penobscot Bay. Moderately low temperatures, about 13 C, were found often between the islands of Casco Bay. These low temperatures indicate an active vertical mixing, associated with tidal currents, that transports water warmed at the surface downward and cold water upward.

Where tidal mixing is reduced, offshore from Cape Ann and in the landward confines of Casco Bay, surface temperatures over 17 C and pronounced stratification occurred. When these high temperatures were observed off Cape Ann, the weather was sunny and calm, or a light wind caused very little mixing. Within Casco Bay temperatures of 17 C or more were observed during a period when fogs were prevalent, allowing heating in clear spells in the daytime and a minimum of cooling at night.

INTRODUCTION

In this paper the ways in which solar radiation is retained by the coastal water of the Gulf of Maine are identified. The first, tidal mixing, is associated with coastal topography; the second and third, wind mixing and superficial diurnal heating, depend on variations in the weather from day to day. Observations in the summers of 1966 and 1967 were made close to shore and in the embayments of the Maine coast (Fig. 1), regions only slightly explored by Bigelow (1914, 1924). The most intensive investigations were made during the foggy summer of 1967, and the effect of this type of weather on the temperature of the water is considered.

In summer in the Gulf of Maine, a surface layer of high temperature is separated from the coastline by cool water (Bigelow, 1914, pl. 9). The band of cool water is narrow on the western side of the Gulf but wide in the northeast and eastern sections. Twenty miles off Cape Ann on the western side, the surface water is often over 20 C, whereas at the shoreline temperatures as low as 12 C may occur (Bigelow, 1924). Across the mouth of the Bay of Fundy, on the eastern side of the Gulf, surface temperatures are 10 C and less (Bigelow, 1924). It is here that tidal currents are very strong (2 knots)

[1]Received for publication December 26, 1967.

[2]Contribution No. 2053 from the Woods Hole Oceanographic Institution. This study was supported by U.S. Atomic Energy Commission Contract AT(30-1)-1918 (Ref. No. NYO-1918-161).

J. Fish. Res. Bd. Canada, 25(12): 2609–2621, 1968.
Printed in Canada.

and consequent vertical mixing carries the heat absorbed at the surface downward with maximum effectiveness. But elsewhere along the coast, where surface temperatures are lower than offshore, one may infer (Bigelow, 1924) that tidal mixing is important in cooling the surface water and warming deeper water.

At Portland Lightship, lying some 6–7 miles off the western coast of the Gulf of Maine (Fig. 1), the surface temperature reaches 15 C at the end of July (Day, 1959, 1963), with a pronounced decrease to 10 C between 10 and 15 m and a gradual change to about 7 C at 40 m. This well-developed thermocline is the result of much more gentle mixing processes than those present at the entrance to the Bay of Fundy. Important among these processes must undoubtedly be the effect of the wind.

If there were no mixing by tidal currents or wind, the thermocline should lie within the first meter below the surface by late afternoon of a sunny day. According to Sverdrup et al. (1942, table 57), 73% of the total solar energy is absorbed between the surface and 1 m in average coastal water. An incident radiation of 545 cal per cm^2 per day, an amount representative of predominantly clear summer weather in the western Gulf of Maine, would raise the mean temperature of the upper meter of water by 4 degrees C and of the second meter of water by only 0.53 degrees C. This indicates how superficial heating by incident radiation alone is and how dependent the heating of the coastal water is on tidal and wind mixing.

METHODS AND ESTIMATES OF CURRENT VELOCITIES

All water temperatures were obtained by a bathythermograph capable of recording to 60 m. Additional temperatures at the surface were taken by thermometer. Maximum and minimum air temperatures were read daily from weather bureau-type thermometers from July 9 to July 30, 1967. The thermometers were placed on a seaward-facing porch (roofed over), on an exposed hillside (see Fig. 4), at an approximate elevation of 20 m. Salinity samples were taken by a Van Dorn sampler, and the salinities were determined by conductivity.

Estimates of mean current velocities, for the principal embayments between Portland and Isle au Haut Bay, were made by computing the intertidal volumes landward of the boundaries indicated by zigzag lines in Fig. 2–4 and dividing these volumes by the cross-sectional areas at the boundaries. The narrow Sheepscot and Damariscotta rivers (Fig. 2) had high velocities, 0.66 and 0.87 knots respectively, wide Muscongus Bay the low velocity of 0.2 knots, and Penobscot and Isle au Haut bays an intermediate value of 0.5 knots. At the outer boundaries of central and western Casco Bay, velocities of 0.65 and 0.83 knots respectively were higher than at the inner boundaries, 0.36 and 0.25 knots. This difference is particularly marked for western Casco Bay, where the openings between the outer islands, constituting the outer boundary, are narrow and contrast with the wide stretches of open water, across which lies the inner boundary.

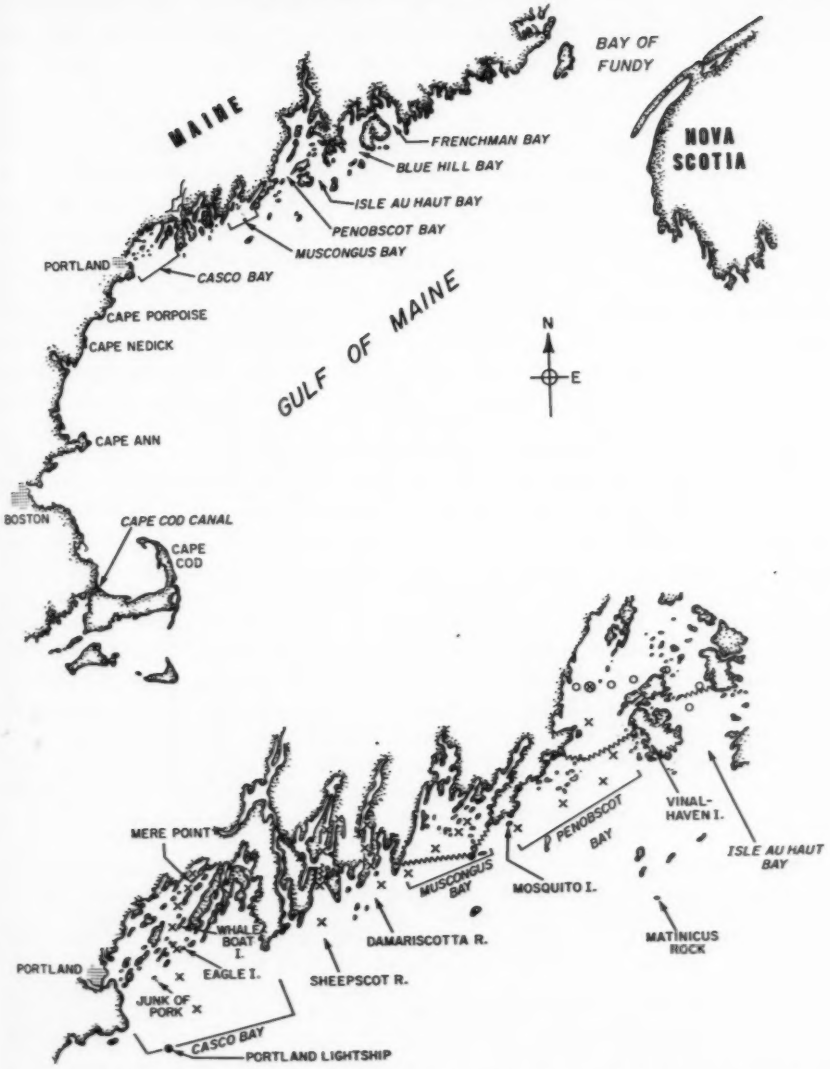


FIG. 1. The Gulf of Maine (*upper*) and Maine coast (*lower*) from Portland to Isle au Haut Bay. × and ○ mark positions where temperatures were taken. Zigzag lines show where mean tidal velocities were computed.

SURVEYS OF THE COAST NORTHEAST OF PORTLAND

In Casco Bay in late July of 1966 stratification was well developed at the seaward and landward ends of the section taken (Fig. 2). Stratification was less marked and the surface water was a little cooler in the vicinity of

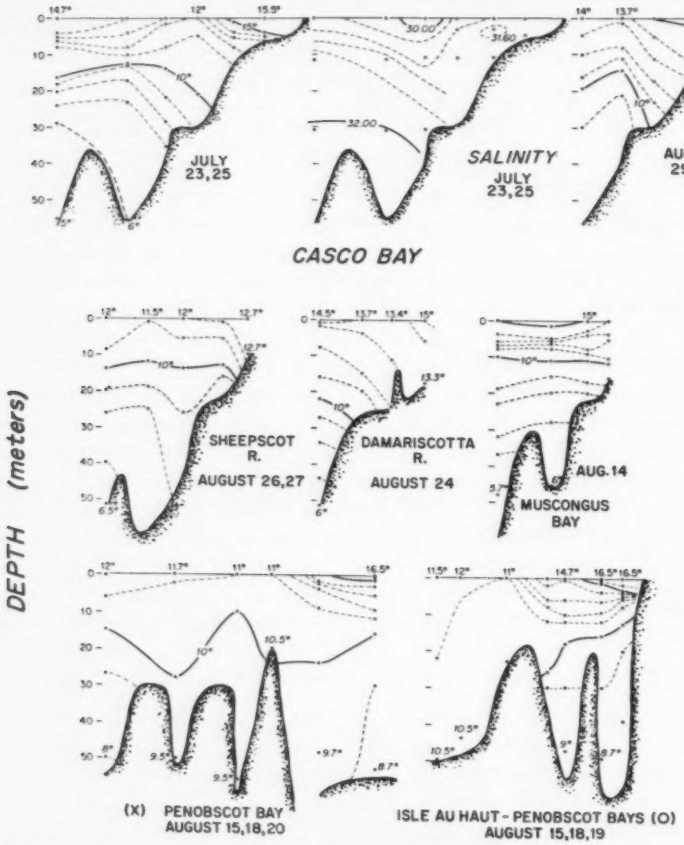


FIG. 2. Distributions of temperature on representative days in 1966 in the waters of the Maine coast between Portland and Isle au Haut bays. × and ○ in Fig. 1 indicate where temperatures were taken. Sections run from open ocean (reading from left to right) into the landward confines of the bays.

Eagle and Whaleboat islands.[3] It is here that the Bay is congested by islands and the current pronounced. At the end of August a similar section showed no distinct differences in the degree of stratification but did show a somewhat greater depth of warm water.

Sections up the narrow embayments, the Sheepscot and Damariscotta rivers, revealed less stratification than in the open waters across Muscongus

[3]The salinity profile shows only a partial relationship to the temperature profile. There is, however, some indication of greater mixing near Whaleboat Island than elsewhere along the salinity section. Greater mixing at Whaleboat Island than landward is well shown, by both temperature and salinity distributions, during the following summer in Fig. 3, section D.

Bay (Fig. 2). In the deep Sheepscot River the effect of mixing of near-surface water with the abundant cold water beneath was to produce a cool surface layer (11.5–12.7 C), the 10 C isotherm lying close to the 10 m depth. In the shallower Damariscotta River, mixing appeared both to cool the surface slightly (to 13.4 from 15 C) and to carry warmth downward, allowing no 10 C water above depths of 20 m. In Muscongus Bay, with its much weaker current and lack of congestion of islands and shoals in the seaward parts (where most of the section was taken), the surface water was close to 15 C, the 10 C isotherm was at 10 m, and deep water was the coldest observed (5.7 C near 50 m) in the three sections. When the survey party was crossing Muscongus Bay there was a light southerly wind, but on the preceding 2 days a northwester blew and at times blew hard (20 mph, approx). All 3 days were clear. Heat absorbed at the surface during these clear days must have been carried down primarily by the turbulence induced by the wind.

Four stations from Mosquito Island to Vinalhaven Island in Penobscot Bay and three in Isle au Haut Bay (Fig. 2) had surface temperatures of 12 C or less and very little stratification. In the inner parts of Penobscot Bay the the water was stratified and the surface records over 16 C. Offshore the temperature of the surface water decreases east of Muscongus Bay (Bigelow, 1924; Fish and Johnson, 1937; Sherman, 1966), and at Matinicus Rock the August average is 12 C (Bumpus, 1957). Since the depth to either side of Vinalhaven Island is less than in many places northward in Penobscot Bay and a fairly pronounced current (mean = 0.5 knots) exists in these shallow areas, it is reasonable that the same cool water should occur near Vinalhaven Island as at Matinicus Rock. But in the wide, deep, inner areas of Penobscot Bay, mixing is reduced and stratification can occur. Within Frenchman Bay, just east of Penobscot Bay, Seiwell (1930) found a maximum of 15.4 C at the surface and a stratified water mass.

SURVEYS IN CASCO BAY

The observations shown in Fig. 2 were made in 1966; much more intense observations were made in Casco Bay in 1967. Along the length of the central portion of Casco Bay the depth of the isotherms on July 10 and 11, 1967, fluctuated somewhat, though the 10 C isotherm tended to be near the 10 m depth (Fig. 3A). Surface temperatures ranged from 12.5 C near Whaleboat Island to 17.8 C at the head of the Bay off Mere Point. During the total of 9 hr of observation on July 9 and 10 at anchor off Eagle Island (B), where there is considerable current, there were several periods when the isotherms, particularly that for 10 C, changed considerably in depth, suggesting disturbance of the water layers in passing in or out of the opening at Eagle Island. At 8:00, 9:00, and 10:00 AM on July 9, with an incoming tide, large quantities of isothermal water occurred respectively at middepths, from the surface to 12 m, and from 20 m to the bottom. On the following day nearly isothermal water occurred from 2:00 to 2:40 PM between 3 and 20 m, and at 6:00 PM a

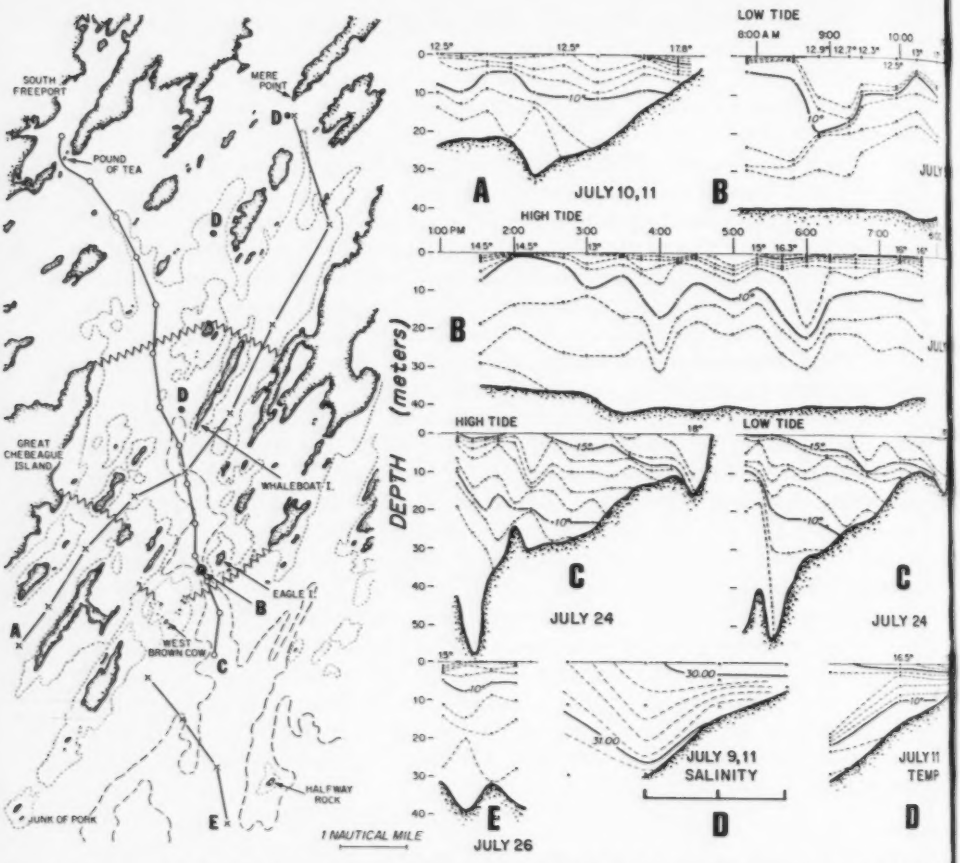


FIG. 3. Temperature distributions in central Casco Bay in July 1967. Salinity is given only for section D, begin at position B. Profiles A and C–E are sections across the Bay. Profiles labelled B are for temperature during incoming tide on July 9 and during the outgoing tide on July 10 while the survey boat was anchored at posi B. The dotted contour indicates approximately the 10 m depth; the dashed contour the 30 m depth. Zigzag show where mean tidal velocities were computed. Depths in profiles at B varied because boat swung at anc Depths in the two profiles of section C varied because it was not possible to return to the same positions exa on return run; seaward-most position not occupied on return run.

small patch of homogeneous water appeared briefly in an otherwise pronounced thermocline. Instances of homogeneous water such as these indicate a sporadic and incomplete vertical mixing at the narrow opening and contrast with the more nearly level isotherms and therefore somewhat less perturbed water of section A. However, perturbations in the water mass passing by the boat at B on the outgoing tide of July 10 were more the exception than the rule.

July 9 was an overcast day and by mid-morning a fairly fresh southerly wind blew. There would be little chance for water coming in from the choppy, open sea beyond Eagle Island to develop a thin, warm, surface layer. But on July 10, a cloudless, warm day with a very light southerly in the afternoon, the outgoing water from the quiet Bay showed a warm superficial layer. At a few stations at the southern end of section A the warm layer was perhaps too thin to detect with the bathythermograph, since the thermometer gave a higher reading at the surface.

Two weeks went by before section C was made — weeks of fog that often cleared landward of the islands in early afternoon but remained throughout the day toward the sea (as observed from an air-temperature station at the southern end of Great Chebeague Island (Fig. 4)). Section C was made on a gray, windy afternoon, starting at high tide off West Brown Cow beyond the confines of islands, arriving 2 hr and 40 min later near Pound of Tea, and was then repeated on the return to West Brown Cow at low tide. The temperature profiles on both runs indicated that the Bay water had warmed considerably, when compared with section A, the 10 C isotherm lying at 20 m instead of 10 m, the 15 C isotherm being now well below the surface for much of the distance, and a temperature of 18 C occurring at the extreme landward position. There is some evidence of vertical mixing one third of the distance from the sea on the first run, suggesting again the mechanism by which heat at the surface is transferred down. But outside of the islands, on July 26 (section E), the 10 C isotherm was above 10 m, and this was due, it is suggested, both to the less tidally disturbed water and to the more fog-shrouded, less sunlit character of the weather seaward of the islands than landward of them. Section E was done on the first clear, blue day to break the prolonged period of fog, and the 13 and 14 C isotherms were very close to the surface.

Sections in western Casco Bay (Fig. 4) were taken from mid-July to early August 1967. There is a considerable body of open bay enclosed behind Cushing, Peaks, Long, and Great Chebeague islands, and separated from central Casco Bay by extensive tide flats northwestward from Cousins Island and between Cousins and Great Chebeague islands. The principal opening to the sea is between Pumpkin Nob and Long Island, but shallower openings lie between Cushing Island and Portland Head, and between Long and Little Chebeague islands. Warm surface water over a pronounced thermocline was present on July 17 in the innermost part of the Bay (section A). But on the outgoing tide or at low tide at the shallow openings (C, right hand end, and F) the water was nearly isothermal, and at the deep opening only weakly stratified (E). Here, off Pumpkin Nob, the 10 C isotherm reached 30 m but rose steadily to less than 10 m to form a marked thermocline out to sea. The pronounced current and vertical mixing off Pumpkin Nob appeared to affect the more open water half way out to Junk of Pork. High tide conditions showed considerable mixing landward of Pumpkin Nob (B, middle portion) but a moderate degree of stratification in the narrows at Pumpkin Nob (section D).

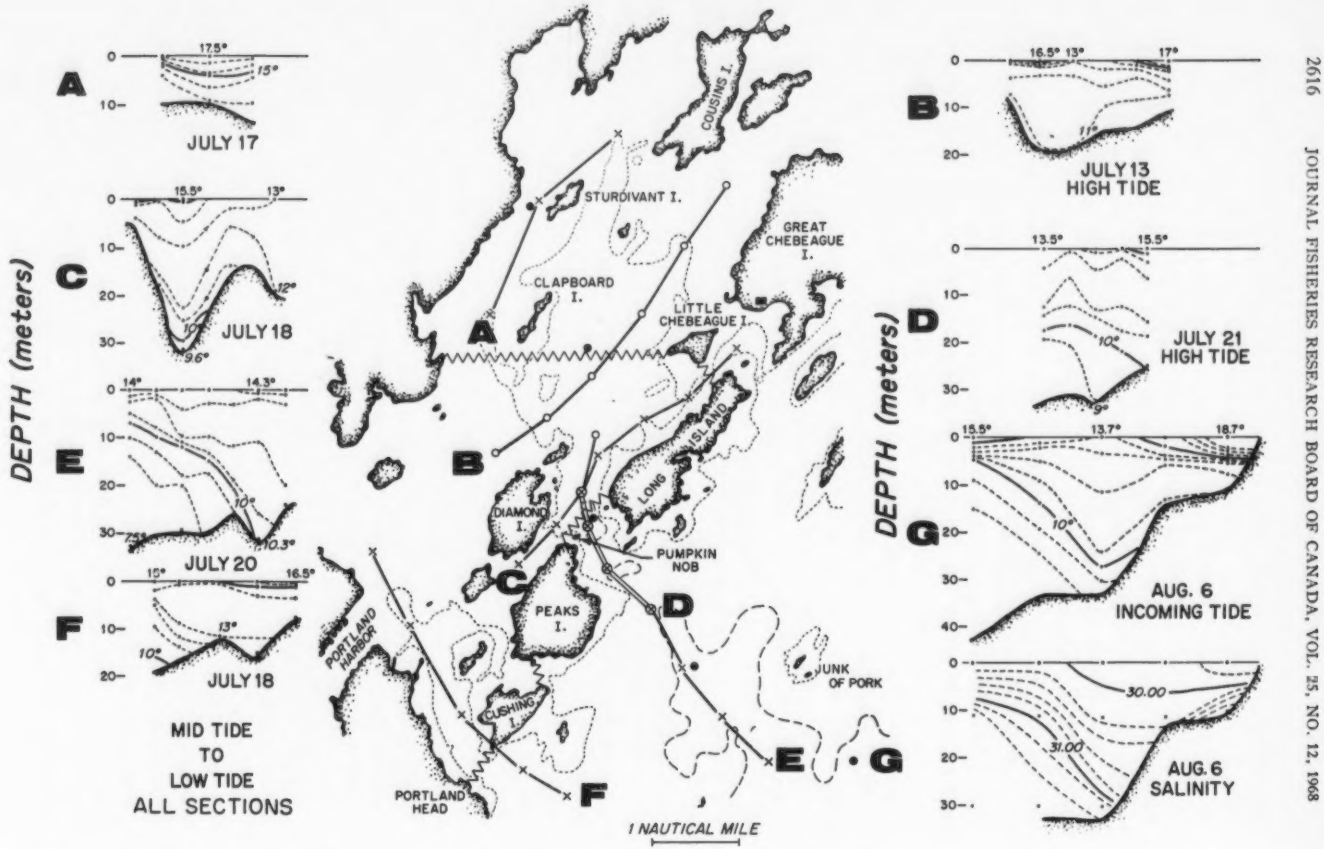


FIG. 4. Temperature distributions in western Casco Bay in 1967. Section G is indicated by solid circles. Salinity is given for section G only. The 10 m depth is indicated by a dotted contour, the 30 m depth by a dashed contour. Zigzag lines are boundaries where currents were computed. The black square on Great Chebeague Island shows where the air temperatures were taken.

These various features were seen also in early August (G), when, in addition, the vertical mixing off Pumpkin Nob resulted in a distinct lowering of the surface temperature. (The salinity profile for this section is remarkably like the temperature profile.)

The warmest water in Casco Bay, 18.7 C, and also the most strongly stratified, was in section G (Fig. 4). This was recorded at about 8:00 AM; the morning was clear, though overcast, after a previous afternoon that was locally clear and an evening of very dense fog. The sections in Fig. 4 were made during brief clearings, with usually overcast sky and winds usually less than 5 mph. Thin, warm surface layers were detected here and there, as behind Diamond Island (B), but this feature seemed less marked than on July 10, off Eagle Island (Fig. 3B).

SURVEYS SOUTH OF PORTLAND

Sections south of Portland (Fig. 5) in early July 1966, and early August 1967, showed poorly stratified water and lowered surface readings near Cape Nedick (10–11.2 C) and Cape Ann (12 C). The highest temperatures occurred offshore, 19.5 C in July and 17 C in August. Offshore temperatures differed considerably, and these differences were related to the weather. Section C in July, with high surface temperatures and intense stratification, was done on the second of 2 clear, sunny days, with morning calms and afternoon southerly winds less than 10 mph (approx); section B, with lower surface temperatures, was done on the following morning, when it was overcast and windy (over 10 mph). In August, just the reverse occurred; B had sunny, nearly calm weather, a high surface temperature, and intensely stratified near-surface water; C had overcast sky, a northeast wind blowing 10–15 mph, lower surface temperatures, and lesser stratification.

TEMPERATURE DIFFERENCES IN THE UPPER 10 M

The most intense stratification occurred in the offshore waters to the south and north of Cape Ann, 14 bathythermograph lowerings showing a difference of 7 C or more in the upper 10 m (Fig. 5). The greatest difference was 10.5 degrees C/10 m. Only one difference as great as 7 degrees C/10 m was found in the waters northeast of Portland. This was in the innermost part of Casco Bay (Fig. 4G).

Where stratification was most pronounced, as about Cape Ann, the surface temperature was highest. Of the 14 lowerings showing a 7 degree C gradient or more in the upper 10 m, 10 had surface temperatures from 17 to 19.5 C. In landward parts of Casco Bay, eight surface temperatures were 17 C or over. The highest was 18.7 C with a 7 degrees C/10 m gradient west of Sturdivant Island (Fig. 4G). At Mere Point there was a surface reading of 17.8 C and a gradient of 6.8 degrees C/10 m (Fig. 3A). Thus a high surface temperature and a fairly intense stratification may occur in the inner parts of Casco Bay. However, the gradients were considerably less than off Cape

The 10 m depth is indicated by a dotted contour, the 30 m depth by a dashed contour. Zigzag lines are boundaries where currents were computed. The black square on Great Chebeague Island shows where the air temperatures were taken.

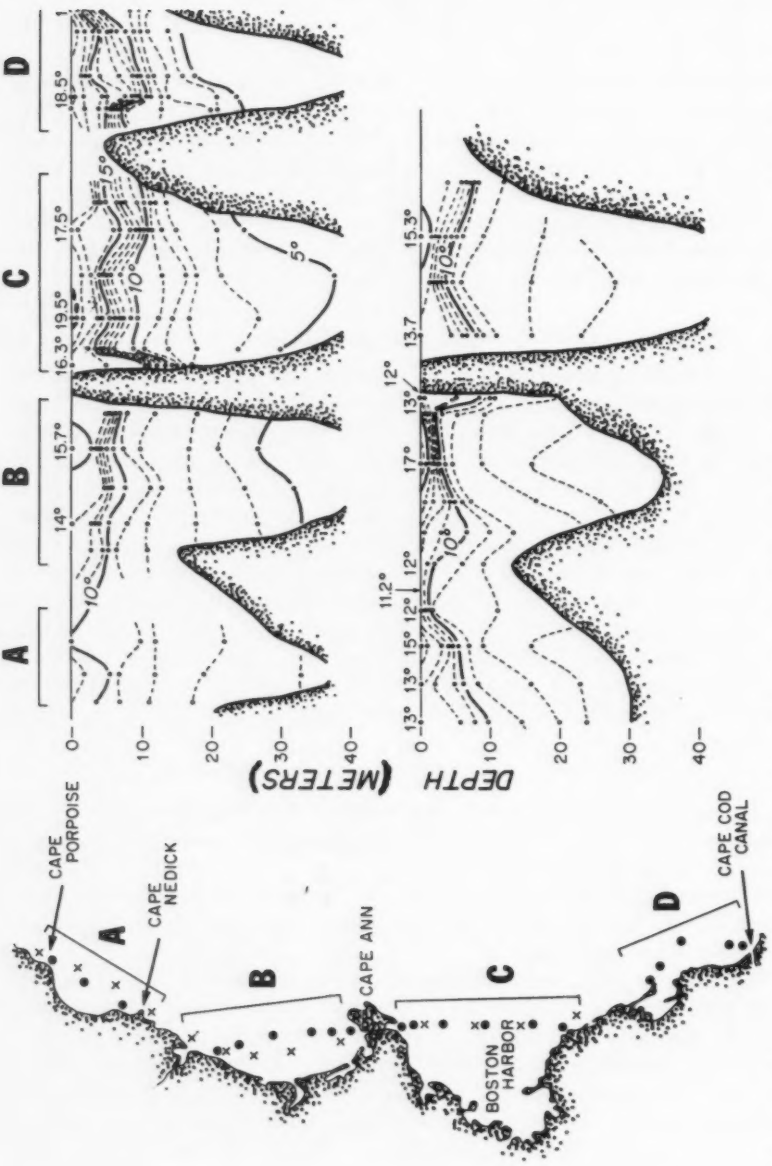


FIG. 5. Temperature distributions from Cape Porpoise to Cape Cod Canal, July 8–11, 1966 (*upper profile*) and from Cape Porpoise across Boston Harbor, August 11–12, 1967 (*lower profile*).

Ann, indicating that tidal movements do appreciably disturb the water, even in these sequestered parts of the Bay. The high surface temperatures (17–18 C) near Pound of Tea were associated with slight gradients (Fig. 3C), and here the currents are fairly strong.

The high surface temperatures in Casco Bay in 1967 were not solely the result of a minimum of vertical mixing, as in offshore waters further south. Furthermore, they were somewhat higher than the average values at Portland,[4] which are 15.3 and 15.9 C for July and August. Possibly the insulating effect of quiet, foggy nights helped produce these high temperatures.

CONTROL OF SURFACE TEMPERATURE OF CASCO BAY IN JULY 1967

For the period of July 9–30, 1967, daily minimum air temperatures at Great Chebeague Island are compared with surface water temperatures in the passages between the outer islands, and temperatures at Portland with water temperatures of the inner portions of central and western Casco Bay (Fig. 6). These comparisons indicate that, on the average, the gradient of heat flow is from air to water in the passages when the daily temperature is lowest, but that there is no obvious gradient either way in the inner portions of the Bay when daily temperatures reach their minima.

Daily maximum and minimum air temperatures are compared (Fig. 6) with maximum water temperatures at the innermost parts of the Bay and with water temperature of 13 C or below recorded in the passages between the outer islands. Also is indicated the extensiveness of fog as seen from the southern end of Great Chebeague Island and records of visibility and wind at night at Portland. From these data we suggest the following considerations.

The protracted duration of fog, particularly at night, coupled with the calm to light wind conditions, should reduce to a minimum radiational or evaporational heat losses from the water to the air at night. The heat absorbed at the surface during the day, particularly during the afternoon behind the outer islands where the fog often disappeared, would tend to remain in the water during the night. This tendency would be most marked near the openings between the outer islands, where vertical mixing is active in transferring heat down. In the innermost parts of the Bay, however, where the highest surface water temperatures exceeded somewhat the minimum air temperature, some loss of heat from the water surface may occur briefly during a 24-hr period and contribute appreciably to the approximate nighttime equilibrium of air and water temperature. Thus, it is possible that the high surface temperatures of the innermost parts of the Bay were held in check by air temperature, to some degree. But, on the whole, the control of the surface temperature would appear to lie in a simple balance between daytime absorption of heat and a perpetual, though locationally variable, downward loss due to vertical mixing.

[4]These averages are from 1873 to 1888 (Bumpus, 1957). It is assumed that such values have not changed over the years, for there seems to have been no long-term change in summer temperatures at Boothbay, 30 miles away (Bumpus and Chase, 1965).

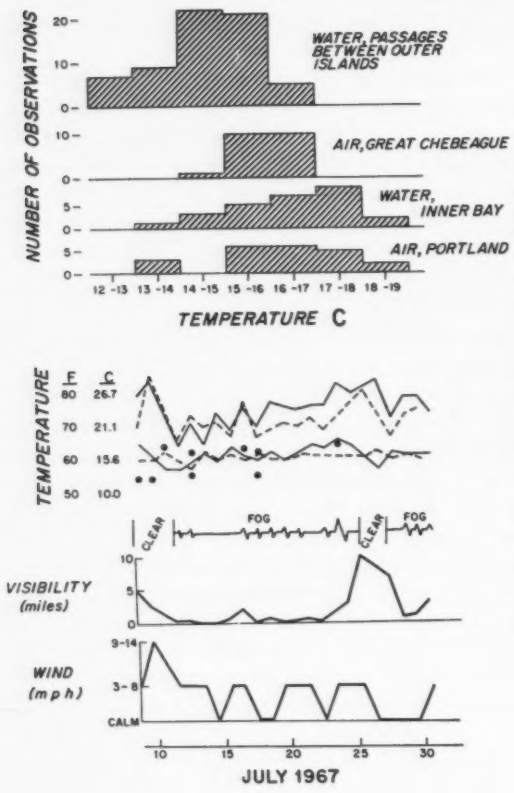


FIG. 6. Frequency distributions of all surface water temperatures in passages between outer islands and in the inner bay, and of daily minimum air temperatures, July 9–30, 1967, at Great Chebeague Island and at Portland. Daily maximum and minimum air temperatures, July 9–30, 1967, at Portland (solid lines) and at Great Chebeague Island (broken lines); surface water temperatures of 17 C or over and 13 C or under are shown by solid circles. Occurrence of fog between the outer islands and mainland, as observed from Great Chebeague Island (breaks in the line indicate clearings behind the islands in the afternoons) and the daily visibility and wind velocity at Portland at 1:30 AM (taken from daily weather maps) are also shown.

CONCLUSIONS

It was only in the inner parts of Casco Bay that the retained heat was sufficient to bring the surface water temperature into approximate nighttime equilibrium with the air temperature. Between the outer islands the absorbed warmth was insufficient to prevent mixing from lowering surface temperatures below minimum air temperatures. Thus, records near 17 C toward the headwaters and 13 C about the openings to the ocean constituted distinctive hydrographic features of the Bay. Equally distinctive were the low temperatures of about 11 C near Cape Nedick, in the Sheepscot River, and adjoining Vinalhaven Island in Penobscot Bay, and the high temperatures of 17 C or more in the offshore waters near Cape Ann. The low values should be fairly constant, since they were controlled by tidal mixing. The high values, however, were more variable, since they appeared to depend not only on reduced mixing but on favorable weather conditions. Off Cape Ann, sunny, calm weather seemed to be required; in Casco Bay diurnal fog, with heat loss at the surface minimized, was an important contributing factor.

REFERENCES

BIGELOW, H. B. 1914. Explorations in the Gulf of Maine, July and August, 1912, by the U.S. fisheries schooner "Grampus". Oceanography and notes on the plankton. Bull. Museum Comp. Zool., **58**: 31–147.

1924. Physical oceanography of the Gulf of Maine. Bull. Bur. Fish., **40**: 511–1027.

BUMPUS, D. F. 1957. Surface water temperature along Atlantic and Gulf coasts of the United States. U.S. Fish Wildlife Serv., Spec. Sci. Rept., Fish., **214**: 1–153.

BUMPUS, D. F., AND JOSEPH CHASE. 1965. Changes in the hydrography observed along the east coast of the United States. Intern. Comm. Northwest Atlantic Fish., Spec. Publ. No. 6. p. 847–853.

DAY, C. G. 1959. Oceanographic observations, 1958, east coast of the United States. U.S. Fish Wildlife Serv., Spec. Sci. Rept., Fish., **318**: 1–119.

1963. Oceanographic observations, 1963, east coast of the United States. Ibid., **406**: 1–59.

FISH, C. J., AND M. W. JOHNSON. 1937. The biology of the zooplankton population in the Bay of Fundy and Gulf of Maine with special references to production and distribution. J. Biol. Bd. Canada, **3**: 189–322.

SEIWELL, H. R. 1930. Oceanographic investigations in the inshore waters of the Gulf of Maine. Science, **71**: 194–195.

SHERMAN, KENNETH. 1966. Seasonal and areal distribution of zooplankton in coastal waters of the Gulf of Maine 1964. U.S. Fish Wildlife Serv., Spec. Sci. Rept., Fish., **530**: 1–111.

SVERDRUP, H. U., M. W. JOHNSON, AND R. H. FLEMING. 1942. The oceans, their physics, chemistry, and general biology. Prentice-Hall, New York. 1087 p.

Cryogenic Preservation of Atlantic Cod (*Gadus morhua*) Sperm[1]

By M. S. Mounib, P. C. Hwang, and D. R. Idler

Fisheries Research Board of Canada
Halifax Laboratory, Halifax, N.S.

ABSTRACT

Cryogenic preservation of cod sperm, with retention of fertilizing capacity, was achieved. Sperm were deep frozen to −79 C or −196 C in the presence of protecting agents. Of the conditions tested, most satisfactory freezing was accomplished in a mixture containing 1 part semen and 3 parts of a medium that consisted of 40 parts 0.4 M NaCl–0.1 M glycine: 8 parts of 1.3% sodium bicarbonate: 10 parts of glycerol. A freezing rate of 5 degrees C/min was more successful than one of 1 degree C/min.

When frozen sperm were stored at −196 C for periods up to 60 days the average fertility was 36 ± 12% (seven samples) compared with 79 ± 6% (seven samples) for fresh sperm on the same batch of eggs. Successful storage of cod sperm at −79 C for a year was achieved.

INTRODUCTION

Since the introduction of glycerol as a protective agent (Rostand, 1946; Polge et al., 1949) for sperm against the deleterious effect of subzero temperature, major progress has been made in cryogenic preservation of sperm of a number of mammalian species without seriously impairing their fertilizing capacity.

There has been limited success with the freezing of fish sperm. Blaxter (1953) obtained 80% fertility with herring (*Clupea harengus*) sperm which were obtained from frozen testis of spawning herring. Hepworth (1962) and Mitchum (1963) were unsuccessful in freezing sperm of rainbow trout. Chinook salmon sperm were motile after being frozen in buffered dimethyl sulfoxide (Hodgins and Ridgway, 1964); the same procedure, however, was not successful when applied to the Atlantic salmon (*Salmo salar*) (Truscott et al., 1968). Recently, Horton et al. (1967) and Hoyle and Idler (1968) reported limited success in freezing sperm of steelhead trout (*Salmo gairdneri*) and Atlantic salmon respectively.

The primary goal of the present investigations was to preserve sperm of cod (*Gadus morhua*) in the frozen state and have them retain the capacity to fertilize eggs.

MATERIALS AND METHODS

Semen and Eggs

During the year 1964–65, milt and roe were collected from cod by application of external pressure (stripping). Care was taken to exclude excreta,

[1]Received for publication July 5, 1968.

J. Fish. Res. Bd. Canada, 25(12): 2623–2632, 1968.
Printed in Canada.

and the semen and eggs were collected in small jars and stored on crushed ice. In 1968, some eggs were obtained by dissection, and transported from Newfoundland to the laboratory in an insulated box containing ice (*c* and *d* batches in Table V). Other eggs were obtained from cod held at the laboratory.

Motility of Spermatozoa

Motility was induced by dilution of sperm on a microscope slide with excess ice-cold sea water; examination was by phase contrast microscopy at a magnification of 630×. An arbitrary grading system from 0 to 5 was used to assess motility of spermatozoa. Zero denoted no motility.

Diluents

These included (*a*) modified Cortland medium (Truscott et al. 1968); and (*b*) sodium chloride medium containing 40 parts of 0.4 M NaCl–0.1 M glycine, and 8 parts of 1.3% $NaHCO_3$.

Protective Agents

Commercial glycerol was used without purification. Ethylene glycol was distilled to remove a slight discoloration.

Suspending Medium

Sodium chloride medium was used for suspending whole semen and preparing washed sperm (1 sperm:3 medium) to be stored in the nonfrozen state.

Washed Sperm

Whole semen was placed in the suspending medium (1 semen:3 medium) and centrifuged in the cold room (approx 2 C) at 800 *g* for 1 hr; seminal plasma was decanted and the sperm were resuspended in a sufficient amount of the medium to bring the final volume to that before decanting.

Freezing Experiments

The experiments were conducted during two periods, 1964–65 and 1968, and slightly different techniques were used.

experiments in 1964–65[2]

Sperm were suspended in the freezing medium (23.8% glycerol in sodium chloride medium), and penicillin (50,000 IU/10 ml) was added. The suspension was mixed gently and then distributed to glass ampoules (1 ml) that had been placed on crushed ice. The ampoules were sealed and left to equilibrate for a period of half an hour; immediately before freezing sperm the ampoules were gently inverted a few times. Freezing of sperm was carried out either slowly or rapidly. For slow freezing, beakers filled with acetone of different temperatures (–10, –20, and –40 C) were prepared. The sealed ampoules were

[2]These experiments were carried out by M. S. Mounib.

bathed in acetone (0 C) in a thermos flask. The temperature in the flask was brought down at a rate of 1 degree C/min by adding suitable amounts of the appropriate cold acetone, until the temperature reached −25 C, at which point dry ice was added to bring the temperature to −79 C. Fast freezing of sperm was achieved by placing the sealed ampoules in a thermos flask and adding a slush of acetone and dry ice.

EXPERIMENTS IN 1968[3]

Sperm were diluted gradually with the freezing medium (23.8% or 17% of glycerol in sodium chloride medium; 15% ethylene glycol in modified Cortland medium) during a 30-min period. One milliliter of extended semen was placed in each ampoule, which was sealed under nitrogen without any equilibration period. These steps were carried out with the material on crushed ice.

The ampoules were placed in an insulated box or wire basket and left in a freezer room (−27 C) for 1 hr. One ampoule was left unsealed to receive a thermocouple used to give continuous temperature readings. The temperature of fluid inside the ampoules was decreased at an average rate of 1, 3, and 5 degrees C/min, respectively, down to −27 C. The ampoules were then removed from the freezer room and plunged into a slush of dry ice and acetone (−79 C) for 30 min. Finally, the ampoules were immersed in liquid nitrogen (−196 C).

FERTILITY TESTS

EXPERIMENTS IN 1964–65

Sperm were thawed at room temperature for 10–15 min, mixed with 10–15 ml of cod eggs in a petri dish for 2 min, and filtered sea water was added. The petri dishes with their contents were transferred to either a refrigerator (2 C) or a refrigerated incubator (5 C), and after a few days the eggs were microscopically examined for fertilization (Forrester, 1964; Ryder, 1882). In one series of tests, the petri dishes with their contents were covered with gauze and placed in a tank provided with running sea water. The gauze was used to prevent the loss of eggs from the petri dishes during transfer. Samples of eggs were microscopically tested from time to time until hatching was observed.

EXPERIMENTS IN 1968

Ampoules were taken from liquid nitrogen or dry ice–acetone slush and warmed under running tap water (approx 15 C) for 1–2 min. Ampoules were unsealed immediately and motility of spermatozoa was examined. Sperm (0.5 ml) were added to eggs (ca. 5000) in 50-ml Erlenmeyer flasks and mixed well. Chilled (1 C) sea water (ca. 30 ml) and penicillin–streptomycin mixture (1000 IU/flask) were then added. After 1 or 2 days incubation at 3–5 C, random samples of eggs were examined microscopically at a magnification of 100×. In one series of tests, eggs were allowed to hatch, and the larvae appeared to be normal.

[3]These experiments involued P. C. Hwang and D. R. Idler.

RESULTS

The results of a typical experiment to test the motility of nonfrozen sperm are shown in Table I. Sperm from whole semen retained their motility for approximately 1 week, whereas in whole semen with penicillin, sperm

TABLE I. Motility scores of whole and diluted semen, and washed sperm of cod.[a]

Date (1964)	Whole semen		Diluted semen		Washed sperm with penicillin
	Without penicillin	With penicillin	Without penicillin	With penicillin	
Apr. 20	4.5	4.5	4.5	4.5	2
" 22	4	4.5	4.5	4.5	2
" 25	4	4	4	4	2
" 27	4	4	4	4	2
" 29	3	4	4	4	2
" 30	2	4	4	4	2
May 5	1	3.5	4	4	2
" 10	0	1.5	1	4	2
" 12	0	0.5	0	2	1
" 15	0	0	0	0.5	0

[a]Sperm of all treatments were kept in centrifuge tubes covered with parafilm at 0 C. Treatments with penicillin consisted of 50,000 IU/10 ml every 7 days. The scoring system ranged from nonmotile (0) to maximum motility (5).

maintained their motility for 2 weeks. Sperm diluted in the sodium chloride medium showed good motility for 2 weeks and the addition of penicillin extended this period to 3 weeks. Washed sperm with penicillin had a relatively low motility, however, but was maintained for at least 3 weeks. It was observed that the suspension of washed sperm was less slimy in texture than that of the whole semen.

The effect of washing, and slow and fast freezing of sperm on their motility is shown in Table II. Sperm were kept frozen (−79 C) for a long period, and from time to time their motility was examined by thawing ampoules from each group. Freezing of sperm depressed their motility and the depression was more obvious with sperm that had been washed or fast-frozen. After storage for a period of more than a year (May 5, 1964 to July 17, 1965), sperm retained their motility (Table II).

The importance of determining fertility as the criterion for successful preservation of sperm has been suggested (Truscott et al., 1968). The fertilizing capacity of treated cod sperm is shown in Table III. Extended semen had a fertilizing capacity comparable with that of fresh sperm. Fast-frozen sperm showed a relatively low percentage of fertilization compared with slow-frozen sperm, whereas the fertilizing capacity of washed sperm was comparable with that of sperm which had not been washed. The first hatching was observed after 21 days in eggs fertilized by fresh or washed sperm and after 22 days in

TABLE II. The effect of washing, and slow and fast freezing[a] of sperm on motility.

Date	No. of samples	Motility score: Washed sperm slow-frozen	Motility score: Whole semen slow-frozen	Motility score: Whole semen fast-frozen
May 5, 1964 (immediately before freezing)	2	2	4.5	4.5
June 6, 1964	3	1	3	1.5
Dec. 10, 1964	2	1.5	3	1
Mar. 2, 1965	2	1	2	1
Apr. 1, 1965	2	1	2	1
July 17, 1965	2	1	2	1

[a]The slow rate was 1 degree C/min with dry ice–acetone; fast freezing was by direct immersion of sealed ampoules in a slush of dry ice–acetone (–79 C).

TABLE III. Fertilizing capacity of nonfrozen and frozen sperm.

	% of fertilization
Whole semen	76
Whole semen suspended in NaCl medium with 23.8% glycerol and not frozen	80
Whole semen suspended in NaCl medium with 23.8% glycerol and fast-frozen[a]	40
Washed semen suspended in NaCl medium with 23.8% glycerol and slow-frozen[a]	60
Whole semen suspended in NaCl medium with 23.8% glycerol and slow-frozen	65

[a]The slow rate was 1 degree C/min with dry ice–acetone; fast freezing was by direct immersion of sealed ampoules in a slush of dry ice–acetone at –79 C (1964–65 experiments). Fertility tests on frozen sperm were performed after 7 days of freezing.

eggs fertilized by slow- or fast-frozen sperm. Also, sperm (1964–65) that had been slow-frozen and preserved for about 11 months still retained their fertilizing capacity (18% from 300 eggs), although this was lower than that of fresh sperm (30%, 300 eggs).

The early series of experiments (1964–65) showed the possibility of preserving cod sperm by freezing, so a systematic study was conducted to improve the method. Preliminary examination of freezing medium and cooling rate was based on the motility of spermatozoa.

Two different freezing media were tested: a modified Cortland medium containing 15% ethylene glycol, and sodium chloride medium with 23.8% glycerol. Sperm were diluted with an equal amount of freezing medium and cooled at a rate of 5 degrees C/min, down to –27 C. When the samples were thawed, it was found that the motility score of spermatozoa in glycerol medium (4) was higher than that in ethylene glycol (1). Volumes of extender were then varied from 1 semen:1 medium to 1 semen:3 medium; higher viability was found with the latter ratio.

Three different concentrations, 23.8, 17.2, and 9.4%, of glycerol in sodium chloride medium were tested. Sperm were frozen at a rate of 5 degrees C/min down to −27 C, then suddenly cooled to −79 C by immersion of the ampoules in a slush of dry ice–acetone. The motility score of spermatozoa after thawing was 3, 4, and 0, respectively.

Next, different rates of freezing were tried in the presence of 17.2% glycerol; these were 1, 3, and 5 degrees C/min down to −27 C. Sperm that had been frozen at a rate of 5 degrees C/min gave better motility scores than those frozen at 1 degree C/min; sperm frozen at a rate of 3 degrees C/min had intermediate motility scores.

The relatively greater efficacy of the lower glycerol concentration was confirmed when fertility was the criterion employed (Table IV). Thus, preliminary examination of motility of spermatozoa suggested that suitable conditions for freezing cod sperm might reasonably include a 5 degrees C/min cooling rate with an extender containing 17.2% glycerol in sodium chloride medium.

TABLE IV. Motility and fertility of cod sperm extended (1 semen:3 medium) in different concentrations of glycerol.

	Concentration of glycerol (%)	Motility score	Fertility (%)
Whole semen	0	5	96.5
Whole semen	0	5	95.0
Extended semen	23.8	3	74.0
" "	23.8	3	54.0
" "	17.2	4	74.0
" "	17.2	4	95.0

The results of a series of experiments designed to investigate these preliminary conclusions and to study storage in the frozen state, are given in Table V. These results suggest that 17.2% glycerol is superior to 23.8% glycerol, since in all but two instances low fertility was obtained with sperm frozen in 23.8% glycerol at the preferred freezing rate (5 degrees C/min). An average freezing rate of 5 degrees C/min was effective, whereas 1 degree C/min was unsatisfactory in all cases. When frozen sperm were stored at −196 C for periods up to 60 days, the average fertility was 36 ± 12% (seven samples) compared with 79 ± 6% (seven samples) for fresh sperm on the same eggs.

DISCUSSION

The present investigation has unequivocally demonstrated that sperm of cod can be frozen and thawed successfully. The variation in fertility after freezing and frozen storage suggests that the frozen sperm are not equivalent

TABLE V. Motility and fertility of cod sperm after freezing and frozen storage.

No. of series	Cooling rate (*degrees C/min*)	Glycerol (%)	Storage temp (*C*)	Days in storage: 0 time[a] (*d*, 1)[b] M[c]	0 time F(%)[d]	3 (*c*, 3) M	3 F(%)	8 (*c*, 2) M	8 F(%)	15 (*b*, 4) M	15 F(%)	25 (*b*, 2) M	25 F(%)	30 (*b*, 1) M	30 F(%)	60 (*a*, 4) M	60 F(%)
I	5	23.8	−196	3	0	4	9	4	3.5	4	12	3	17	3	89	2	5
II	1	23.8	−196	1	0	1	0	1	0	2	0	1	0	1	0	1	0
III	5	17.2	−196	4	81	3	19	5	30	3	5	4	7	4	80	4	30
IV	1	17.2	−196	0	0	2	0	0	0	2	0	0	0	0	0	2	0
Control	–	–	–	–	96	5	48	5	68	5	90	5	68	5	96	5	90
V	5	23.8	−79	4	70	3	3										
VI	1	23.8	−79	2	0	0	0										
VII	5	17.2	−79	3	73	3	7										
VIII	1	17.2	−79	1	0	2	0										
Control	–	–	–	5	96	5	48										

[a]0 time refers to sperm tested within 5 hr after treatment.

[b]Numbers within parentheses refer to batches of sperm; letters within parentheses refer to batches of eggs.

[c]Motilities (M) are ratios, nonmotilic (0) up to 5.

[d]Percentage of eggs fertilized, each value represents the average when one vial of sperm mixed with two flasks of eggs. Control refers to fresh sperm without extender.

in all respects to fresh sperm. From the experiences of others with mammalian species, much experimentation with freezing conditions will be required to achieve this ideal state.

The successful use of a bicarbonate buffer in the medium has as its basis the recent demonstration of a carbon dioxide fixation by cod sperm (Mounib and Eisan, 1967, 1968). The beneficial effect of glycine on mammalian (Roy and Bishop, 1954; Flipse and Almquist, 1956) and sea urchin sperm (Tyler, 1953) has been mentioned by previous workers. Satisfactory results have been obtained in this study when the glycerol concentration in the medium was between 23.8% and 17.2%. Contrary to its successful use in subzero storage of salmon sperm, the modified Cortland medium with ethylene glycol was not suitable for freezing of cod sperm.

The 1968 experiments showed that in contrast to the high fertility of samples that were cooled at 5 degrees C/min, no fertility was found in sperm cooled at 1 degree C/min down to −27 C. The results at the slow-freezing rate are not in accord with those of 1964–65 experiments; differences in techniques between the two sets of experiments might have contributed to this discrepancy. In the 1964–65 experiments, the ampoules were sealed under air, the cooling rate was measured in the acetone where the ampoules were being bathed, and frozen sperm were thawed by leaving them at room temperature for 10–15 min, whereas in the 1968 experiments, the ampoules were sealed under nitrogen, the cooling rate was measured by means of a thermocouple inserted in one of the ampoules, and thawing of sperm was effected by placing ampoules of frozen sperm under running water (ca. 15 C) for 1–2 min.

A freezing rate 4 degrees C/min was found better than 1 degree C/min, after 10 min equilibration in ram spermatozoa (Jones, 1965). A temperature decrease of 5 degrees C/min was found to be optimal for trout spermatozoa protected with 5% dimethyl sulfoxide (Horton et al., 1967); slight or vague motility was found in some samples which showed no fertility. This finding again emphasizes that only a rough correlation exists between motility and fertilizing capacity of fish sperm (Truscott et al., 1968). According to Hoar (1957) "fertilization occurs in the majority of fishes externally when eggs and spermatozoa are discharged in close proximity; the sexual products perish within minutes unless they unite." This implies that sperm of fish are able to fertilize eggs without undergoing certain changes, i.e. a capacitation process similar to that in the rabbit sperm (Austin, 1951; Chang, 1951) is not required. However, the observation that in a few cases motile sperm of cod were not able to fertilize eggs suggests that such sperm were decapacitated (Chang, 1957). As yet, it is difficult to speculate on the factors that decapacitate motile sperm of fish, i.e. make them unable to fertilize eggs.

Fertility tests before and after freezing show that sometimes freezing did not cause serious diminution of either motility or fertility (Table V). It is probably best not to speculate on reasons for the variable fertility obtained with sperm after frozen storage until more data are available. A few factors

which interfere with fertilization tests include differences in the percentage of mature eggs among the different batches of eggs (May, 1967), contamination of water (Wood and Dunn, 1948), and breakage of eggs during extrusion (Inaba et al., 1958).

REFERENCES

AUSTIN, C. R. 1951. Observations on the penetration of the sperm into the mammalian egg. Australian J. Sci. Res., Ser. B, **4**: 581–596.

BLAXTER, J. H. S. 1953. Sperm storage and cross-fertilization of spring and autumn spawning herring. Nature, **172**: 1189–1190.

CHANG, M. C. 1951. Fertilizing capacity of spermatozoa deposited into the fallopian tubes. Ibid., **168**: 697–698.
1957. A detrimental effect of seminal plasma on the fertilizing capacity of sperm. Ibid., **199**: 258–259.

FLIPSE, R. J., AND J. O. ALMQUIST. 1956. Diluters for bovine semen. IX. Motility of bovine spermatozoa in milk-glycine and egg yolk-glycine diluents with and without glycerol. J. Dairy Sci., **39**: 1690–1696.

FORRESTER, C. R. 1964. Laboratory observations on embryonic development and larvae of the Pacific cod, *Gadus macrocephelus* Tilesius. J. Fish. Res. Bd. Canada, **21**: 9–16.

HEPWORTH, W. G. 1962. Study of the preservation of fish sperm by freezing. Wyoming Game Fish. Comm. Completion Rept. FW-3-R-9.

HOAR, W. S. 1957. The gonads and reproduction. *In* M. E. Brown [ed.] The physiology of fishes. Vol. I. Academic Press, Inc., New York. p. 287–321.

HODGINS, H. O., AND G. J. RIDGWAY. 1964. Recovery of viable salmon spermatozoa after fast freezing. Progressive Fish-Culturist, **26**: 95.

HORTON, H. F., J. R. GRAYBILL, AND A. S. H. WU. 1967. Cryogenic preservation of viable fish sperm. Dept. Fish. Wildlife Completion Rept., Oregon State Univ., Corvallis, Ore.

HOYLE, R. J., AND D. R. IDLER. 1968. Preliminary results in the fertilization of eggs with frozen sperm of Atlantic salmon, *Salmo salar*. J. Fish. Res. Bd. Canada, **25**: 1295–1297.

INABA, D., M. NOMURA, AND K. TOMINAYA. 1958. Studies on the improvement of artificial propagation in trout culture. I. On the interference of the broken eggs and the effect of egg washing method. Bull. Japan. Soc. Sci. Fish., **23**: 758–761.

JONES, R. C. 1965. The use of dimethyl sulphoxide, glycerol and reconstituted skim milk for the preservation of ram spermatozoa. II. The influence of diluent composition and processing time during freezing to –79 C with dimethyl sulfoxide or glycerol or both compounds. Australian J. Biol. Sci., **18**: 887–900.

MAY, A. W. 1967. Fecundity of Atlantic cod. J. Fish. Res. Bd. Canada, **24**: 1531–1551.

MITCHUM, D. W. 1963. Study of the preservation of fish sperm by freezing. Wyoming Game Fish. Comm. Completion Rept. FW-3-R-10, 33-37.

MOUNIB, M. S., AND J. S. EISAN. 1967. Fixation of carbon dioxide by cod sperm. Federation Proc., **26**: 645.
1968. Carbon dioxide fixation by spermatozoa of cod. Comp. Biochem. Physiol., **25**: 703–709.

POLGE, C., A. U. SMITH, AND A. S. PARKES. 1949. Revival of spermatozoa after vitrification and dehydration at low temperatures. Nature, **164**: 666.

ROSTAND, J. 1946. Glycérine et résistance du sperme aux basses températures. Compt. Rend., **222**: 1524–1525.

ROY, A., AND M. W. H. BISHOP. 1954. Effect of glycine on the survival of bovine spermatozoa *in vitro*. Nature, **174**: 746.

RYDER, J. A. 1882. A contribution to the embryography of osseous fishes with special reference to the development of the cod (*Gadus morhua*). U.S. Fish. Comm. Rept. p. 455–606.

TRUSCOTT, B., D. R. IDLER, R. J. HOYLE, AND H. C. FREEMAN. 1968. Subzero preservation of Atlantic salmon sperm. J. Fish. Res. Bd. Canada, **25**: 363–372.

TYLER, A. 1953. Prolongation of life span of sea urchin spermatozoa and improvement of the fertilization-reaction, by treatment of spermatozoa and eggs with metal chelating agents (amino acids, versene, DEDTC, Oxine, Cupron). Biol. Bull., **104**: 224–239.

WOOD, E. M., AND W. A. DUNN. 1948. Fact and fiction in spawn taking. Progressive Fish-Culturist, **10**: 67–72.

Differences between North American and European Populations of *Balanus balanoides* Revealed by Transplantation[1]

By D. J. Crisp

University College of North Wales
Marine Science Laboratories, Menai Bridge, Anglesey, Wales

ABSTRACT

Transplants of specimens of *Balanus balanoides* from North Wales to Newfoundland, Canada, confirmed two innate differences between European and North American forms of the species. Breeding took place later in transplanted European populations. The eggs of the European form, though maturing later and therefore at a slightly lower temperature than the North American form, were distinctly smaller.

The time of breeding both in the North American and European forms was earlier at higher latitudes, at higher shore levels, and in shelter.

INTRODUCTION

The breeding season of several population of the circumboreal Arctic species *Balanus balanoides* from different localities between latitudes 40° and 45°N on the North American side of the Atlantic has been given by Barnes (1958) and may be compared with that of populations of the same species from a wider latitudinal range on the coast of Europe, extending from Northern Norway to southwest England (Crisp, 1959a). If the populations studied can be regarded as representative of those throughout the European and North American sides of the Atlantic Ocean, there appear to be minor, but significant, differences in reproductive physiology in these morphologically indistinguishable races. The North American race not only breeds earlier at corresponding latitudes, but its embryos develop more rapidly at the same temperature, and its eggs are significantly larger. The differences were retained at least for a year after transplantation from North America to Europe, and were therefore thought likely to be innate (Crisp, 1964).

Further observations have now been made on breeding in this species over a wider latitudinal range on the North American coast, and an experimental population was transferred in the reverse direction, from Britain to Newfoundland, to compare the reproductive cycle of the two races under identical climatic conditions.

METHODS

Specimens of *B. balanoides* attached to mussel shells were sent by air to St. John's, Newfoundland, and transplanted, using quick-setting cement,

[1]Received for publication March 13, 1968.

J. Fish. Res. Bd. Canada, 25(12): 2633–2641, 1968.
Printed in Canada.

to a position in the normal *Balanus* zone near, or slightly above, mean tide level. A semi-sheltered shore, Horse Cove in Conception Bay, was chosen for this experiment. Transplantation was completed between August 11 and 18, 1962, well in advance of the breeding season.

Samples were removed weekly for examination of the reproductive state during the period of fertilisation and oviposition, and thereafter at longer intervals. The percentage carrying fertilised egg masses, the stage of embryonic development of the eggs, the dimensions of the eggs, and the condition of the male reproductive system were noted in each sample.

Corresponding observations were made on samples of *B. balanoides* native to Newfoundland growing in the same environment as the transplants, and on samples native to Wales growing at the site from which the transplants had been collected. Two samples were obtained from Woods Hole, Mass., during October 1962 and were examined for further comparison; other populations were examined in the field in Nova Scotia during the breeding season. To conform with the Canadian Government's legislation on the introduction of living exotic fish, the transplantation experiment was terminated and all imported barnacles removed on February 10, 1963 before any liberation of nauplii had taken place.

The samples collected in Nova Scotia were studied to determine the influence of such environmental factors as tidal level, wave exposure, and the age of the individual on the time of fertilisation. The median date of fertilisation of samples taken from different environments was obtained by backdating early embryo stages present in the mantle cavity (Crisp, 1959b).

RESULTS OF TRANSPLANT EXPERIMENTS

The Breeding Cycle

Figure 1 illustrates the progress of fertilisation and embryonic development in the native Newfoundland population, the transplanted population from North Wales, and the original population remaining in North Wales. The median date of fertilisation of the North Wales population, whether in North Wales (53°13′N lat) or in Conception Bay, Newfoundland (47°34′N lat), lay between November 10 and 13, 1962, and was evidently influenced very little by transplantation. The median date of fertilisation of the Newfoundland population was much earlier, on about October 4, 1962. A few had been fertilised by late September and all were fertilised by the middle of October. By comparison, the median date of fertilisation of *B. balanoides* growing at mean tide level at Woods Hole, Mass. (41°32′N lat) was on approximately October 22, 1962. The median date at various locations in Nova Scotia varied from October 9 to 20, 1962, according to tidal level and exposure (Table I), and thus was intermediate in time between Newfoundland and Woods Hole, though the two samples from Cape Breton Island, N.S., were exceptionally late in relation to their high latitude, due perhaps to exposure to higher sea temperatures caused by local outflow of warm water from the Gulf of St. Lawrence during late summer or fall. It is known from studies of

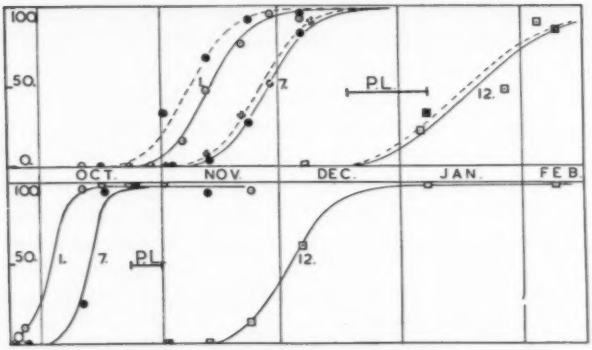


FIG. 1. Breeding and embryonic development of *Balanus balanoides* native to North Wales and to Newfoundland. The progress of fertilisation is shown by open circles (stage 1). Full circles and squares represent embryonic development to the stage of early limb bud rudiments (stage 7), and eyed nauplii (stage 12) respectively. P.L. = period over which penis is shed. *Upper*: North Wales population in Menai Bridge (solid lines) and after transplantation to Newfoundland (broken lines and crossed symbols). *Lower*: breeding behaviour of population indigenous to Newfoundland. *Ordinate:* percentage of population having reached the reproductive stage indicated. *Abscissa:* date of observation.

this species in Europe that the date of breeding is influenced by environmental factors operating at this time (Crisp and Clegg, 1960) and may be delayed by higher temperatures (Crisp, 1957, 1959a).

TABLE I. Latitudinal variation in median date of fertilisation of *Balanus balanoides* in October 1962.

Place	N lat	Tidal level	Median date of fertilisation (*Oct. 1962*)
Woods Hole, Mass., USA	41°32′	M.T.L.-H.W.N.[a]	22
Yarmouth, N.S.	43°49′	M.T.L.-H.W.N.	15
Lunenburg, N.S.	44°20′	H.W.	12
Peggy's Cove, N.S.	44°30′	M.T.L.	20
Herring Cove, N.S.	44°32′	M.T.L.	13
Smith's Beach, N.S.	44°34′	H.W.	10
Purcell's Cove, N.S.	44°35′	M.T.L.	19
Parker's Cove, N.S.	44°50′	H.W.	13
		L.W.	20
Liscomb, N.S.	45°02′	H.W.	9
Margaretsville, N.S.	45°02′	M.T.L.-H.W.N.	12
Port Hood, Cape Breton Is., N.S.	46°01′	H.W.	14
Neil's Harbour, Cape Breton Is., N.S.	46°46′	H.W.	15
Horse Cove, Conception Bay, Nfld.	47°34′	M.T.L.-H.W.N.	4

[a]M.T.L. = mean tidal level; H.W.N. = high water neap; H.W. = high water; L.W. = low water.

From sea temperatures published by Fuglister (1947) and corresponding air temperatures (United States Navy Department, 1955) there is in August a reduction of sea temperature between Cap Cod and southeast Nova Scotia from about 20 to about 16 C, and in November from about 10 to about 7 C; similarly the sea temperatures in southeast Newfoundland are approximately 3 degrees C lower. Air temperatures fluctuate more widely and fall more sharply with the approaching winter, but show the same latitudinal trend.

Thus, despite minor local anomalies, earlier breeding of more northerly populations within the latitudinal range covered is a characteristic of North American populations just as it is of European ones. But the North American populations, when compared with European populations at similar latitudes, breed at least a month earlier.

Figure 1 also shows the progress of development. The Newfoundland population, having fertilised a month earlier, maintained their lead in development throughout the winter. The transplanted specimens developed only slightly more slowly in Newfoundland than they did at their place of origin in North Wales. Unfortunately, because of the aforementioned government regulations, the experiment had to be terminated before hatching and liberation took place.

After fertilisation, *B. balanoides* undergoes a period of anecdysis terminated by a moult in which the penis is lost; the testes and vesiculae seminales atrophy at this time. Both native North American and transplanted European barnacles showed similar changes, but the former were some 6 weeks in advance of the latter. Half the native Newfoundland barnacles had shed their penes between October 24 and November 2, 1962, whereas the corresponding date for the transplanted European barnacles was between December 7, 1962 and January 8, 1963.

Egg Size

The sizes of the eggs obtained from samples of 50 individuals are given in Table II. It will be seen that the size is little altered by transplantation. Barnacles from the coast of North America produce significantly larger, and the European specimens smaller, eggs whether they mature and develop in Europe or in America. The population living in Newfoundland, well to the north of Woods Hole, produce somewhat larger eggs than those of barnacles from the Woods Hole district. As expected, late stage eggs were distinctly larger than early stage eggs.

Effect of Environment on Date of Breeding

Tidal Level

Table III gives the percentage of individuals carrying eggs in samples taken at high and low levels between the tide marks in various localities in Nova Scotia. In all cases the breeding of the high-water populations had progressed further, a higher percentage carrying egg masses. Breeding thus occurs earlier higher up the shore.

TABLE II. Influence of environment and origin on egg size.

Place of origin	Environment during breeding season	Early stage eggs[a]		Late stage eggs[a]	
		Length	Breadth	Length	Breadth
		μ	μ	μ	μ
Horse Cove, Nfld., Canada	Horse Cove	338±7	175±5	392±6	196±3
Menai Bridge, North Wales, U.K.	Menai Bridge	265±5	137±3	305±10	160±4
	Horse Cove	272±6	143±4	325±7	172±4
Woods Hole, Mass., USA	Woods Hole	307±5	155±4	338±6	180±5
	Menai Bridge	328±13	162±6	341±7	178±6

[a]Stages up to appearance of limb buds classified as early (stages 1–9, Crisp, 1954); stages with setae and eyes classified as late (stages 10–13). Standard errors associated with measurements are included.

TABLE III. Effect of tidal level on breeding.

Locality and date		% of sample population bearing egg masses at	
		H.W.[a]	L.W.[a]
	Oct. 1962		
Smith's Beach near Halifax	10	37	0
Margaretsville	12	59	29
Argyle Sound	20		
Adults		96	33
Spat		95	9
Parkers's Cove	22	100	86

[a]H.W. = high water; L.W. = low water.

At Horse Cove, Newfoundland, where the tidal range was much smaller than in Nova Scotia, a similar effect was apparent from observations made in November. Individuals growing near the high-water mark had in general more advanced embryos than those lower down the shore. However, in the sample collected on December 7, 1962 there were a few very small 1st-year individuals, 4–6 mm diam, carrying embryos that were much less advanced than those of the normal sized individuals of 8–10 mm diam. This phenomenon will be considered in the section dealing with the effect of age on breeding.

WAVE EXPOSURE AND SHELTER

At several localities in Nova Scotia the breeding state of barnacles growing in exposed positions was compared with that of barnacles living at the same tidal level in shelter. Table IV shows that fertilisation invariably took place earlier in sheltered situations.

TABLE IV. Effect of wave exposure and shelter on breeding.

Locality and date		% of sample population bearing egg masses when	
		Sheltered	Wave exposed
	Oct. 1962		
Smith's Beach near Halifax, high water	10	52	6
Lunenburg, high water	12	90	2
Jeddore Oyster Pond	13	87	45
Liscomb	13	87	25
Port Hood	15	58	10
Peggy's Cove	20	73	50

AGE OF INDIVIDUALS

In most localities the individuals that have settled in the previous spring form a readily separable size-class. They are referred to as *spat*, to distinguish them from adults in their 2nd or later year of growth. Table V gives the results of two counts in which adults and spat were compared. In both cases the adults fertilised in advance of spat.

A proportion of the smallest spat present at the extreme upper limit of the barnacle zone, especially those living in cracks where growth is reduced, failed to become fertilised in their first year. As mentioned above (p. 2637), there was evidence that a few of such individuals may mature and become fertilised very much later than adults.

TABLE V. Effect of age on breeding.

Locality and date		% of sample population bearing egg masses among	
		>1 year old	<1 year old
Allendale	Oct. 20, 1962	87	17
Argyle Sound	Oct. 20, 1962	74	49

DISCUSSION

Balanus balanoides breeds annually every autumn, and the time at which the eggs are laid is remarkably regular (Crisp, 1959a). The date of breeding is affected, not by the normal variations in temperature and other environmental conditions at the time, but by those some weeks earlier (Crisp and Clegg, 1960). However, if barnacles are collected in late spring or early summer and held in a constant environment in the dark at a temperature of from 4 to

INFECTION BY HEMIONISCUS

10 C, they will breed within a week or two of the normal time (D. J. Crisp and B. Patel, unpublished observations). It appears, therefore, that they are sensitive to environmental influences only for a limited period in late summer and autumn, quite unlike species that can be induced to breed by raising the temperature (Patel and Crisp, 1960). Therefore, the climate at other times of year appears not to be important to the breeding cycle.

The factors that influence breeding at the relevant time are chiefly light and temperature; experiments indicate that a regime of predominantly low light intensity at a temperature of less than 10 C for several weeks is a necessary conditioning experience (Crisp, 1957; Barnes, 1963). In the field, breeding is advanced in places where there is greater shading, greater shelter from wave exposure or water currents, and greater exposure to the air at higher tidal levels (for discussion see Crisp, 1959a). Breeding is also advanced at higher latitudes, though there are of course variations from place to place in response to local differences in meteorological conditions and sea temperatures. These environmental and latitudinal factors have been shown to operate in exactly the same manner on populations on the North American coast and in Europe, but the American form differs from the European in the earlier onset of breeding in identical habitats, the larger size of the egg, and the more rapid development of the embryo. These differences persist after transplantation in either direction, and are therefore quite independent of the environment during the period of gonad maturation. A further difference between the two races lies in the greater susceptibility of the North American form to parasitism by *Hemioniscus balani*, as is shown in Fig. 2, based on data from Crisp (1968). All these differences probably result from genetic responses to the environment, notably to the harsher winters during which the embryos develop, the earlier plankton blooms (see Crisp, 1964), and to the rarity of the parasite *Hemioniscus* in the western Atlantic.

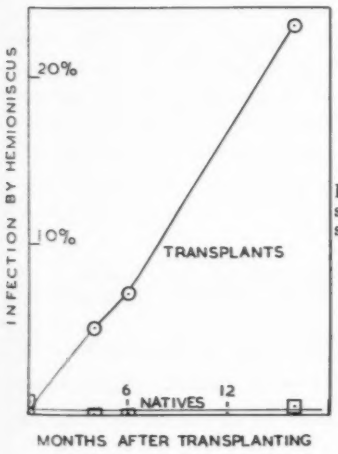


FIG. 2. Infection by *Hemioniscus* of Newfoundland specimens transplanted to Britain. Native North Wales specimens growing in the same locality showed a low rate of infection.

The distribution of this species extends to much more southerly latitudes on the American coast, and its centre of abundance there is considerably further south than in Europe. For this reason the comparison between the breeding of the species in Wales and in Newfoundland is the only one where the latitude is closely comparable. The temperature of the sea during the period of maturation for the 6 weeks prior to fertilisation was about the same at this latitude on the two sides of the Atlantic, though the Newfoundland population fertilised over a month earlier. The populations further south, in Nova Scotia and New England, though they fertilised somewhat later than the Newfoundland population, because of the lower latitude did so at temperatures rather higher than those prevailing in North Wales at the time of maturation and breeding (14 C dropping to 10 C) or in Newfoundland when the native population there was maturing (13 C dropping to 9 C). Thus while the Woods Hole population were maturing, sea temperatures fell only from 17 to 12 C and air temperatures were not much lower. These temperatures are higher than those hitherto quoted (10 C) for conditioning the species in Europe (Crisp, 1957; Barnes, 1963) and suggest that in America, over the southern part of its range at least, *B. balanoides* is probably adapted to mature at higher temperatures than it does in Europe. Probably the rate of fall in temperature, the change in day length, and other factors as well as the actual temperature level may combine in determining when maturation and breeding take place. The two races clearly react differently and breed at different times when the environmental conditions are identical.

ACKNOWLEDGMENTS

I am greatly indebted to Miss Elizabeth Brown for assistance in collecting transplanted specimens from Newfoundland, and to Mr P. S. Meadows for collecting samples of *Balanus balanoides* from Menai Bridge and dispatching them by air. The Nuffield Foundation, Memorial University of St. John's, Nfld., and Dalhousie University, Halifax, N.S., supported me while I was engaged in this research. I wish to thank Mr H. R. Found and Mr H. Bradley, Department of Fisheries of Canada, for their help in arranging for a veterinary inspection of the barnacles at the port of immigration and in obtaining special sanction from the Canadian Government for the temporary introduction of exotic fish.

REFERENCES

BARNES, H. 1958. Regarding the southern limits of *Balanus balanoides* L. Oikos, **9**: 139–157.
1963. Light, temperature and the breeding of *Balanus balanoides*. J. Marine Biol. Assoc. U.K., **43**: 717–725.

CRISP, D. J. 1954. The breeding of *Balanus porcatus* (da Costa) in the Irish Sea. Ibid., **33**: 473–496.
1957. Effect of low temperature on the breeding of marine animals. Nature, London, **179**: 1138–1139.
1959a. Factors influencing the time of breeding of *Balanus balanoides*. Oikos, **10** 275–289.

1959b. The rate of development of *Balanus balanoides* (L.) embryos *in vitro*. J. Animal Ecol., **28**: 119–132.

1964. Racial differences between North American and European forms of *Balanus balanoides*. J. Marine Biol. Assoc. U.K., **44**: 33–45.

1968. Distribution of the parasitic isopod *Hemioniscus balani* with special reference to the east coast of North America. J. Fish. Res. Bd. Canada, **25**(6): 1161–1167.

CRISP, D. J., AND D. J. CLEGG. 1960. The induction of the breeding condition in *Balanus balanoides* (L.). Oikos, **11**: 265–275.

FUGLISTER, F. C. 1947. Average monthly sea surface temperatures of the western North Atlantic Ocean. Papers Phys. Oceanog. Meteorol., **10**(2): 25 p.

PATEL, B., AND D. J. CRISP. 1960. The influence of temperature on the breeding and moulting of some warm-water species of operculate barnacles. J. Marine Biol. Assoc. U.K., **39**: 667–680.

UNITED STATES NAVY DEPARTMENT. 1955. Marine climatic atlas of the world, Vol. 1. North Atlantic Ocean. NAVAER 50-1C-528, Washington, D.C. 275 p.

Experimental Plantings of Brook Trout (*Salvelinus fontinalis*) from Furunculosis-Infected Stock[1]

By L. A. McDermott

University of Guelph
Department of Microbiology, Guelph, Ont.

AND

A. H. Berst

Ontario Department of Lands and Forests
Research Branch, Maple, Ont.

ABSTRACT

Preliminary sampling revealed the presence of furunculosis disease in the resident brook trout population of the southern Ontario trout stream used in this study.

Two plantings of marked yearling brook trout were made in the study area in 1966; one in the spring, and the other in the fall. The spring planting consisted of 1000 brook trout with a predetermined incidence of furunculosis infection and an equal number of trout with no evidence of infection. The fall planting consisted of 2000 brook trout with a known incidence of furunculosis infection.

The stream was electrofished periodically during the 2-year period after the first planting. A total of 445 brook trout (140 of the planted hatchery stock, and 305 resident trout) and 127 fish of associated species were captured and examined for the presence of *Aeromonas salmonicida*, causative agent of furunculosis.

Recovery rates of the "infected" and "noninfected" stocks of brook trout were similar, and there was no evidence of transmission of *A. salmonicida* from the infected fish to the control fish, nor the resident population of brook trout and other species of fish captured.

INTRODUCTION

Among reports on the occurrence of furunculosis disease in fish in natural waters, some have no explanation for its presence (Arkwright, 1912; Duff, 1932; Duff and Stewart, 1933; Fryer and Conrad, 1965; Rabb and McDermott, 1962; Rushton, 1937; Smith, 1960, 1962; Vickers and McClean, 1961; Wood, 1959). Others suggest that furunculosis-infected fish from hatcheries or fish farms are responsible for outbreaks (Fish, 1937; Furunculosis Committee, 1930, 1933, 1935; Plehn, 1909). Still others find no connection between infected hatchery fish and infected fish in natural waters, and some even suggest that the disease is endemic among the resident fish (Davis, 1944; Horne, 1928). Fish (1937) wrote: "So little is known about furunculosis as it may exist outside hatcheries that few facts are available on which to base a conclusion as to

[1]Received for publication July 2, 1968.

J. Fish. Res. Bd. Canada, 25(12): 2643–2649, 1968.
Printed in Canada.

how much actual damage has been done or is being done to trout and salmon research by liberating furunculosis fish."

The present study was undertaken to obtain data on the biology of stocks of brook trout, *Salvelinus fontinalis*, with a previous history of furunculosis disease after they were planted in a trout stream. The study provided data on the biology of resident brook trout and associated species before and after the plantings of hatchery trout from infected stocks.

STUDY AREA

The stream chosen for this study is located in southern Ontario, Canada, and flows into Lake Ontario. Preliminary surveys of the stream system in November 1965 and April 1966 revealed a low incidence of *Aeromonas salmonicida*, causative agent of furunculosis disease, in resident brook trout in the headwaters, approximately 5 miles (8 km) upstream from the study area.

The study area was divided into two adjacent sections, here designated A and B, each approximately 1000 yards (916 m) long and from 10 to 30 ft (3–9 m) wide. They were characterized by alternating pools and riffles, with the depth of water seldom exceeding 5 ft (152 cm) in A and 3 ft (91 cm) in B. The water in the stream was alkaline, with a *p*H of 8.0–8.3, and a total alkalinity of 150–160 ppm $CaCO_3$. The bed is composed largely of sand and gravel with patches of clay, and is moderately sedimented. The flow in the study area during the experiment fluctuated between 20 and 200 ft^3/sec (566 and 5660 liters/sec). Summer water temperatures fluctuated between a minimum of 17 and a maximum of 24 C during the 2 years of the study.

The stream system had for many years supported a substantial population of native brook trout produced by natural reproduction in the headwaters and tributaries. The population was supplemented periodically by plantings of hatchery-reared trout.

MATERIALS AND METHODS

On November 12, 1965, the resident trout population of the stream was sampled and examined to determine the incidence of those carrying *A. salmonicida*. A portable a-c – d-c fish shocker (McCrimmon and Berst, 1963) was employed to obtain the samples of fish.

Experimental plantings of brook trout from a hatchery experiencing mortalities from furunculosis were made in study sections A and B. Two groups of fish were used in the plantings. One group, marked by a right pectoral clip and designated as "infected," came from hatchery stock with a known incidence of *A. salmonicida* carriers. The second group, marked by an adipose clip and designated as "noninfected," came from stock from which *A. salmonicida* could not be isolated. The fish in all plantings were yearlings, ranging in length from 7 to 9 inches (18–23 cm) with no external symptoms of disease.

The first experimental plantings were made April 22, 1966, when 1000 "noninfected" brook trout were distributed as evenly as possible in section A, and 1000 "infected" brook trout in section B. The fish populations of both

sections were then sampled periodically until late August 1966, when there was no further evidence of the planted fish.

The second experimental plantings were made September 20, 1966, when 2000 "infected" brook trout were distributed in sections A and B of the study area.

Periodic sampling of the fish population in the study area was resumed and continued until April 30, 1968. Fish from sections of the stream above and below the study area were also examined. Wherever possible, the heart, liver, spleen, intestine, reproductive organs, and kidney of each fish were examined for the presence of *A. salmonicida* by the methods described by Rabb and McDermott (1962).

The study area was open to public fishing during the regular angling seasons for brook trout, from April 30 to September 15, 1966 and 1967. A limited creel census was conducted during the 1966 angling season to obtain data on the harvest of planted and resident stocks of trout. None of the trout in the creel census was examined for *A. salmonicida*.

The localities of capture of individual resident and hatchery-reared brook trout were recorded in both the creel census and in the periodic sampling by electrofishing. The length and weight of each fish were recorded and, if possible, the sex was determined. Scale samples were taken from resident fish for age determinations.

RESULTS AND DISCUSSION

During the 29 months of the study, 913 fish were examined for the presence of *A. salmonicida* as shown below:

Species	No. examined	Carriers (%)
Salvelinus fontinalis:		
Resident	305	1.0
"Noninfected"	103	0
"Infected"	378	18.2
Catostomus commersoni	74	0
Semotilus atromaculatus	27	0
Rhinichthys atratulus	26	0
Total	913	7.9

A total of 305 resident trout were taken from the stream (Table I). In the preliminary surveys of 1965 and 1966, 92 trout were examined; one male and one female were carriers of *A. salmonicida*. From May to August 1966, 44 trout were taken from the study area; one male was a carrier. From September 1966 to April 30, 1968, 169 trout were obtained from the study area, from above and below the study area, and from the headwaters; none was a carrier.

A total of 103 trout from the planting of "noninfected" hatchery stock were examined (Table II); *A. salmonicida* was not isolated from 95 trout examined before planting nor from 8 trout recaptured by electrofishing.

TABLE I. Incidence of *Aeromonas salmonicida* carriers (as percent of fish examined) in resident brook trout of a southern Ontario stream.

Date	Area sampled	No. examined	Carriers (%)
Nov. 12, 1965	Headwaters	48	4.2
	Study area	14	0
Apr. 22, 1966	" "	30	0
May 13, 1966	" "	18	6.0
June 10, 1966	" "	11	0
Aug. 12 1966	" "	15	0
Oct. 25, 1966	" "	2	0
Jan. 12, 1967	" "	18	0
Apr. 28, 1967	" "	7	0
June 5, 1967	" "	33	0
June 27, 1967	Below study area	10	0
	Headwaters	17	0
Aug. 11, 1967	Study area	18	0
Oct. 18, 1967	Study area	1	0
	Headwaters	19	0
Oct. 31, 1967	Study area	14	0
Apr. 30, 1968	Study area	22	0
	Above study area	6	0
	Below study area	2	0
Total		305	1.0

A total of 378 trout from the planting of "infected" hatchery stock were examined (Table III); in 102 of these taken on April 22, 1966, 11 males and 8 females were carriers. From April 22 to August 12, 1966, of 36 trout recaptured by electrofishing, one male and one female were carriers. In 144 "infected" trout taken on September 20, 1966, 13 males and 18 females were carriers. From the second planting on September 20, 1966 up to April 30, 1968, 96 trout were recaptured by electrofishing; of these, 8 males and 9 females, were carriers. All 17 trout came from the study area.

None of the fish found to be carriers exhibited any external symptoms associated with furunculosis disease. *Aeromonas salmonicida* was not isolated from any of the white suckers, creek chub, and black nose dace taken.

The distribution of *A. salmonicida* in the 72 trout found to be carriers is shown below.

Organs	No. of brook trout		
	Males	Females	Total
Heart only	6	5	11
Liver only	5	3	8
Spleen only	1	2	3
Reproductive organs only	2	3	5
Intestine only	4	4	8
Kidney only	3	7	10
More than one organ	14	13	27

TABLE II. Incidence of *Aeromonas salmonicida* carriers (as percent of fishes examined) among "noninfected" hatchery brook trout.

Date	Area sampled	No. examined	Carriers (%)
Apr. 22, 1966	Hatchery raceway	95	0
May 13, 1966	Study area	4	0
June 10, 1966	" "	1	0
Aug. 12, 1966	" "	1	0
Oct. 25, 1966	" "	0	0
Jan. 12, 1967	" "	0	0
Apr. 28, 1967	" "	0	0
June 5, 1967	" "	0	0
June 27, 1967	Below study area	0	0
	Headwaters	0	0
Aug. 11, 1967	Study area	0	0
Oct. 18, 1967	Study area	0	0
	Headwaters	1	0
Oct. 31, 1967	Study area	1	0
Apr. 30, 1968	Study area	0	0
	Above study area	0	0
	Below study area	0	0
Total		103	0

TABLE III. Incidence of *Aeromonas salmonicida* carriers (as percent of fishes examined) among "infected" hatchery brook trout.

Date	Area sampled	No. examined	Carriers (%)
Apr. 22, 1966	Hatchery raceway	102	18.6
May 13, 1966	Study area	33	6.1
June 10, 1966	" "	3	0
Aug. 12, 1966	" "	0	0
Sept. 20, 1966	Hatchery raceway	144	21.5
Oct. 25, 1966	Study area	72	20.8
Jan. 12, 1967	" "	14	7.0
Apr. 28, 1967	" "	10	10.0
June, 5 1967	" "	0	0
June 27, 1967	Below study area	0	0
	Headwaters	0	0
Aug. 11, 1967	Study area	0	0
Oct. 18, 1967	Study area	0	0
	Headwaters	0	0
Oct. 31, 1967	Study area	0	0
Apr. 30, 1968	Study area	0	0
	Above study area	0	0
	Below study area	0	0
Total		378	18.3

These results indicate the necessity of culturing more than one organ for the presence of *A. salmonicida* in fish examined for furunculosis disease.

Of the 1000 "noninfected" hatchery trout planted in the study area, 8 were recaptured by electrofishing and at least 94 by angling for a total of 102. Of the 3000 "infected" hatchery trout planted, 132 were recaptured by electrofishing and at least 173 by angling, for a total of 305. In both cases, approximately 10% was recaptured. The limited creel census conducted from April 30 to September 15, 1966 is estimated to have accounted for approximately 75% of the angling during that period. A total of 291 man-hr by 102 anglers produced a total of 326 brook trout: 59 were resident trout, 94 were from "noninfected" hatchery stock, and 173 were from "infected" hatchery stock.

The sampling of fish from the stream indicated extensive movement of both "infected" and "noninfected" hatchery stocks in the stream system. The age determinations of resident trout revealed the presence of four year-classes, from young-of-the-year through age III, during each year of the study. This indicated that normal recruitment of brook trout by natural reproduction occurred during the experiment.

Except during the winter periods, the study area was under close surveillance. However, there was no evidence of any mortalities of planted or resident fish. Although the extensive movement of trout from "infected" and "noninfected" stocks provided considerable opportunity for contact between these and resident trout and other species, there was no evidence of transmission of *A. salmonicida* within the fish population. Such factors as the availability of space, the rate of flow, and volume of water in the natural environment of the stream, unlike conditions prevailing in most hatchery raceways, may explain this lack of transmission.

ACKNOWLEDGMENTS

The authors are grateful to Mr G. C. Armstrong of the Fish and Wildlife Branch of the Ontario Department of Lands and Forests who provided helpful advice in the planning of the project and made available the stocks of fish for the experimental plantings. Several members of the staff, particularly Messrs K. Chambers, P. Hartman,,and A. Armstrong were most generous with their assistance. The cooperation of Messrs J. Foote and J. Agnew of the Metropolitan Toronto Region Conservation Authority, who assisted in the selection of the study area and in the collection of field data, is gratefully acknowledged. Thanks are also due to Messrs W. Paterson, P. Hunter, and R. Sonstegard for the collection of field data and for the laboratory examination of fish specimens. Financial support was received from the Ontario Department of Lands and Forests.

REFERENCES

ARKWRIGHT, J. A. 1912. An epidemic disease affecting salmon and trout in England during the summer of 1911. J. Hyg., **12**: 391–413.

DAVIS, H. H. 1944. Infectious diseases among wild fishes. Trans. Am. Fish. Soc., **74**: 21–25.

DUFF, D. C. B. 1932. Furunculosis on the Pacific coast. Ibid., **62**: 249–255.

DUFF, D. C. B., AND BEATRICE J. STEWART. 1933. Studies on furunculosis of fish in British Columbia. Contrib. Can. Biol. Fish., **8**: 103–122.

FISH, F. F. 1937. Furunculosis in wild trout. Copeia, **1**: 37–40.

FRYER, J. L., AND J. F. CONRAD. 1965. Some observations on furunculosis in adult Pacific salmon and steelhead trout. Progressive Fish-Culturist, No. 27. p. 99–100.

FURUNCULOSIS COMMITTEE. 1930. Interim report. H. M. Stationery Office, Edinburgh. 65 p.
1933. Second interim report. H.M. Stationery Office, Edinburgh, 81 p.
1935. Final report. H.M. Stationery Office, Edinburgh. 67 p.

HORNE, J. H. 1928. Furunculosis in trout and the importance of carriers in the spread of the disease. J. Hyg., **28**: 67–68.

McCRIMMON, H. R., AND A. H. BERST. 1963. A portable A.C.–D.C. back-pack fish shocker designed for operation in Ontario streams. Progressive Fish-Culturist, No 25. p. 159–162.

PLEHN, MARIANNE. 1909. Die Furunkuloseepidemie der salmoniden in Suddeutschland. Centralblatt Bakteriol. Parasitenkunde Infektionskrankh. Abt. I. Original Band, **52**: 468–469.
1911. Die Furunkulose der Salmoniden. Ibid., **60**: 609–624.

RABB, L., AND L. A. McDERMOTT. 1962. Bacteriological studies on freshwater fish. II. Furunculosis in Ontario fish in natural waters. J. Fish. Res. Bd. Canada, **19**: 989–995.

RUSHTON, W. 1937. Freshwater fishing problems in the British Isles. Trans. Am. Fish. Soc., **66**: 383–391.

SMITH, ISABEL W. 1960. Furunculosis in salmon kelts. Nature, **186**: 733–734.
1962. Furunculosis in kelts. Freshwater and salmon fisheries research, #27. H.M. Stationery Office, Edinburgh. 12 p.

VICKERS, K. W., AND R. McCLEAN. 1961. Furunculosis in Lough Neagh pollan, *Coregonus pollan*, Thompson. Nature, **191**: 930–931.

WOOD, J. W. 1959. Ichthyophthiriasis and furunculosis in adult Pacific salmon. Progressive Fish-Culturist, No. 21. p. 171.

Multiple Haemoglobins of the Atlantic Salmon (*Salmo salar*)[1]

By N. P. Wilkins

Department of Agriculture and Fisheries for Scotland
Marine Laboratory, Aberdeen, Scotland

ABSTRACT

The haemoglobins of over 500 salmon of different lengths, from Scotland, Greenland, and Canada have been analysed by vertical starch–gel electrophoresis at *p*H 8.1. Complex ontogenetic variations, involving an initial increase and later reduction in the number of fractions evident, have been observed among the anodally migrating haemoglobins. The variations observed have been correlated with changes in length, and the complete development of the anodal haemoglobin complex from the single fraction of small fish to the nine-fraction pattern of adults is outlined. The individual haemoglobin fractions appear to represent structurally distinct molecules whose regulated occurrence at different phases of the life cycle is discussed at the individual and population levels.

INTRODUCTION

In an electrophoretic survey of the haemoglobins of freshwater fishes, Schumann (1959) reported the occurrence of two distinct haemoglobin components in the erythrocytes of the Atlantic salmon (*Salmo salar* L). K. Sick (1961, personal communication) later observed, in the same species, a total of eight haemoglobin components migrating in two broad regions, each comprising four distinct bands. In an analysis of over 300 individual salmon, Koch et al. (1964) observed up to 13 haemoglobin fractions exhibiting both anodic (5 fractions) and cathodic (8 fractions) migration. Moreover, a well-defined developmental sequence in the appearance and disappearance of these fractions was reported.

Subsequent studies by Wilkins (1967) suggested that the analysis might be significantly extended by means of a different method of electrophoresis. Continuing investigations indicated that up to nine anodic and six cathodic haemoglobin components were detectable. Over 500 salmon of different sizes and from widely separated areas have now been examined, and this paper details and discusses the observed ontogenetic development of the haemoglobin at the individual and population levels.

MATERIALS AND METHODS

Hatchery-reared 1- and 2-year-old Scottish parr and 2-year-old smolts were obtained from Invergarry Hatchery in Invernessshire, and wild specimens of parr and smolt were examined from the rivers Conon, North Esk,

[1]Received for publication August 19, 1968.

J. Fish. Res. Bd. Canada, 25(12): 2651–2653, 1968.
Printed in Canada.

and Tweed. Canadian smolts were obtained from the hatchery at Chorlo, New Brunswick.

Adult salmon were sampled from three widely separated geographic areas: the rivers Tweed, North Esk, and Dee in Scotland; the Miramichi River in Canada; the coast and fiords near Godthåb in West Greenland. The fork length of each fish was recorded, and when possible, the sex and state of sexual maturity.

All parr and smolts sampled were from 5 to 20 cm long and sexually immature; they are referred to as juvenile salmon. Adult salmon all exceeded 50 cm fork length and varied in sexual maturity from immature to spent. Two categories of adult salmon may be distinguished: those that mature sexually after one winter in the sea (1+ sea winter salmon), referred to as *grilse*; those that mature sexually for the first time after at least two winters in the sea (2+ sea winter salmon), referred to as *adult salmon*.

Fish were killed by a sharp blow on the head, and blood was collected from the heart with a fine Pasteur pipette or disposable syringe. The fresh blood was thoroughly mixed with an anticoagulant of the following composition: dextrose, 20.5 g/liter; tri-sodium citrate, 8.0 g/liter; sodium chloride, 4.0 g/liter; heparin, 1.0 g/liter (*p*H 7.1). Samples were stored and transported in thermos flasks containing an ice–water mixture. In this way, the whole blood remains in perfect condition for at least 3–4 days, although most of the material was analysed within 24 hr of collection.

The erythrocytes were washed thrice in a large excess of saline, and haemolysed with distilled water or buffer.

Analyses were carried out by the vertical starch-gel electrophoresis technique of Smithies (1959), with a modification ("Penny" buffer, C. Manwell, personal communication) of the lithium–Tris–citrate buffer described by Ferguson and Wallace (1961). Acid gels were prepared using Tris–citrate buffer, *p*H 2.0, with the addition of 0.4% (v/v) of 2-mercaptoethanol in the gel only.

Electrophoresis was carried out at 400–500 v (20–40 ma) for 12 hr in a refrigerator at 0 C. Local heating was minimised by directing an electric fan at the gel during the entire run. The temperature within the gel at the end of the run never exceeded 3 C.

Electropherograms were sliced and stained with *o*-Dianisidine or amido black, and washed in 10% acetic acid until background staining was reduced to a minimum. They were then photographed with transmitted light.

Some gels were subsequently cleared and preserved by heating in an acetic acid – glycerol – water (1:1:7) bath. Cleared gels were allowed to dry at room temperature and wrapped in aluminium foil until optically scanned. Scanning and integration were performed with a "Chromoscan" automatic integrating scanner.

Columns (40 × 2.5 cm) of Sephadex G-200 were equilibrated, and haemolysates prepared and eluted, with phosphate buffer *p*H 7.3, $\mu = 0.02$.

RESULTS

To clarify the nomenclature of the components, the general electrophoretic pattern obtained with adults is presented in Fig. 1. Separation is towards both anode and cathode, but is sharper in the former. As many as nine anodic and seven cathodic components are evident; these are labelled Al to A9 and Cl to C7, respectively. Differences between the anodic components of certain individuals are apparent, whereas the cathodic groups of components show relatively little individual variation.

For reasons presented in the discussion, only anodic components will be dealt with in detail.

Juvenile Salmon

In juveniles, the anodic group of components is considerably less complex than that of adults, with four or less fractions evident (Fig. 2). Three common patterns are presented diagrammatically (Fig. 3), and Table I shows their distribution. It is evident that the patterns represent stages in development of the haemoglobin complex from the one-component pattern α to the four-component pattern γ. The patterns illustrated are in no way definitive; intermediates are observed in some individuals.

Component A4 is present in high concentration in all the juvenile fish. Koch et al. (1966) reported that in the smallest salmon studied, anodic components represented up to 82% of the total haemoglobin content. The proportion of anodic haemoglobin decreased with increase in length, the trend of the curve suggesting that in small ($\sim$4 cm) individuals it reaches 100% asymptotically, and in very young fish cathodic haemoglobin is lacking. A similar trend was observed here, and only trace quantities of cathodic haemoglobin were observed in fish 3.5–4.5 cm long.

Component A3 makes an early appearance, followed closely by component A2. When both occur, as in patterns β and γ, component A3 is invariably more concentrated than A2, which is weakly present; both increase in concentration with increasing length. Component A7, not observed in individuals of less than 11 cm, appears weakly in fish of 11–15 cm, and tends to increase in the larger individuals. In all samples, component A4 is maximally present and does not vary in concentration over the limited range of lengths sampled. No change in the haemoglobin pattern attributable to the parr–smolt transformation has been observed.

Adult Salmon (Including Grilse)

In adult specimens, up to nine anodic components are observed and their relative concentrations exhibit a wide variation. Consequently, many variations in pattern are detectable, certain of which, e.g. that of sample 8 (Fig. 1) in which components A4 and A7 are absent, may appear prominent. In the more prominent patterns, generally one or more components are absent. Large differences in occurrence of components Al, A4, A6, and A7 are evident

(Table II). When the occurrence of each component is plotted against length (in 5-cm intervals) within each sample (Fig. 4), a relation is evident, at least in components A4, A6, and A7.

The analyses strongly suggest that differences in individual components (Table II) reflect differences in mean lengths, and not in the genotype of individuals from separate areas. No component or pattern characterised exclusively the individuals of any area. Moreover, Scandinavian salmon appear not to exhibit any components different from those of Scottish salmon (Koch et al., 1967). It is evident that over a large part of its range the species is homogeneous in the electrophoretic mobility of its haemoglobins, and possibly, therefore, in haemoglobin genotype.

To clarify the observed variations, freshly stained gels were examined and the relative concentration of each haemoglobin band was visually assessed and scored as follows: absent (A), no band evident; weak (W), weakly stained, usually narrow band; medium (M), staining intermediate between "weak" and "strong"; strong (S), intensely stained band, usually oval shaped. All the data from adult specimens, which vary in length from 50 to 100 cm, are presented (Table III) in 5-cm groups (60–64, 65–69, etc.) with the exception of individuals of 85 cm and over, which are presented as a single group because of the relatively small numbers of observations. Within the areas sampled, the mean intensity of A6 increases with increase in length, and that of A4 decreases.

A number of gels were cleared and preserved as described, and were subsequently scanned and integrated. The sequence of categories, absent to strong, was found to reflect reasonably accurately, successively greater degrees of mean optical density, and the categories could be quantitatively related, on the basis of their mean chromoscan integrals, by the values A = 0, W = 5.7, M = 8.2, and S = 12.0. Using these values it is possible to determine the relation between haemoglobin concentration and mean length, and between length and mean haemoglobin concentration as described by Wilkins and Iles (1966). Figures 5 and 6 illustrate these relations. Advancing sexual maturity does not appear to influence appreciably the anodic components; a number of mature and sexually spent individuals exhibited patterns not significantly different from immature and partly mature fish of similar size. Statistical analysis was not carried out on the data on Canadian adults because of the small numbers (22 fish) analysed.

By considering all data from juveniles and adults, it is possible to present, in outline, the complete ontogenetic development of each anodic component.

Component A1

This was not observed in juveniles but was present in 82% of adults, generally in low concentration. In Scottish material, there is a significant trend ($P < 0.05$) to greater concentration with increasing length. A similar trend is not significant in the Greenland data.

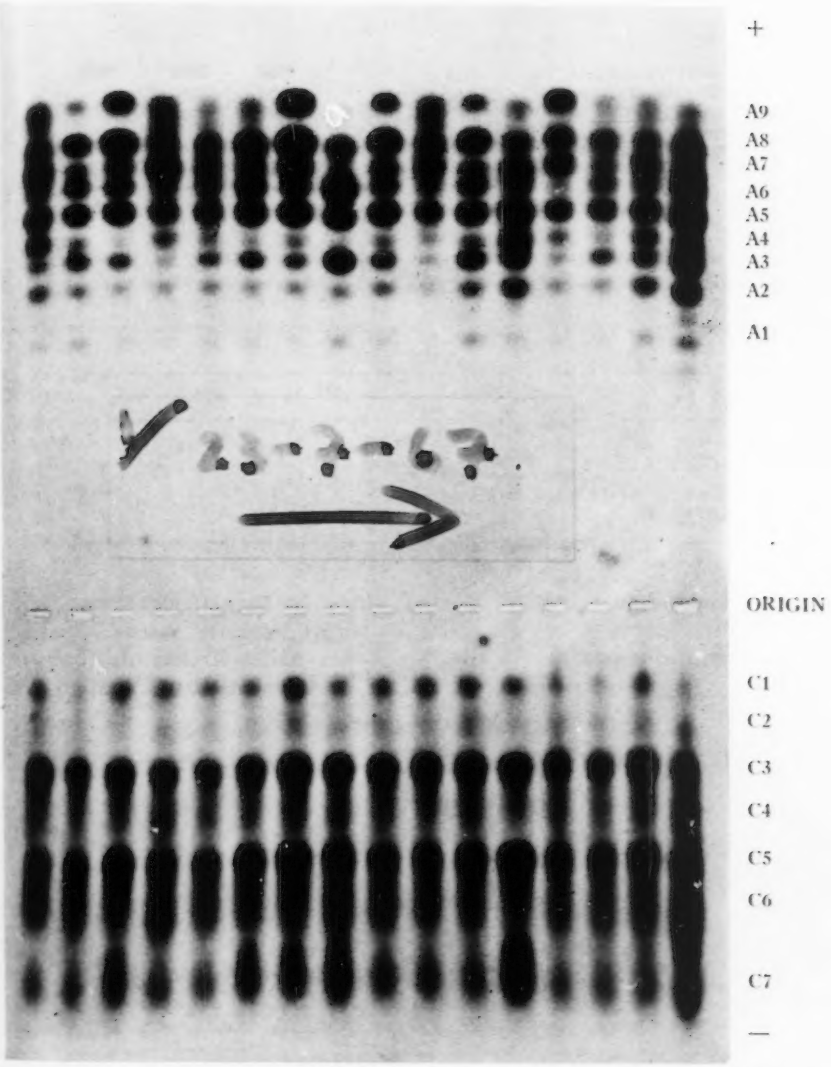


FIG. 1. Amido black stained electropherogram of the haemolysate proteins of adult salmon. All the bands represent haemoglobins, as judged by their colour when unstained, and their positive reaction with *o*-Dianisidine and H_2O_2. Samples 1–16 from left to right. Anodic and cathodic haemoglobins are numbered from the origin. Electrophoretic conditions: lithium–Tris-citrate buffer, *p*H 8.1; 400 v constant voltage, 12 hr.

Wilkins — J. Fish. Res. Bd. Canada

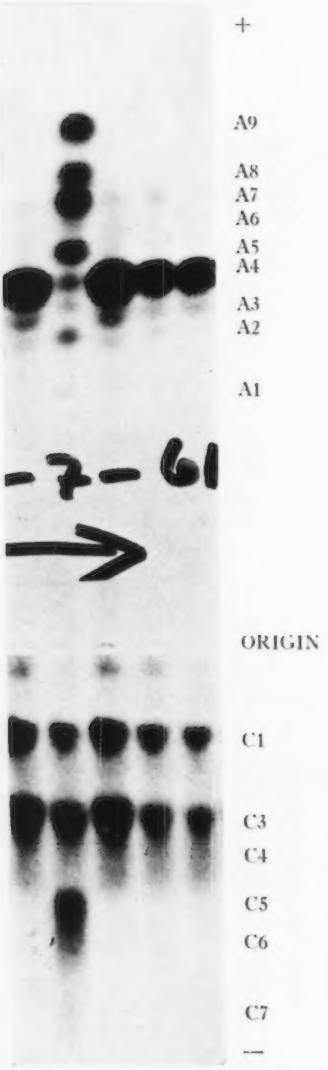


FIG. 2. Amido black stained electropherogram of the haemoglobins of four juvenile and one adult salmon. Samples 1–4 in direction of the arrow. Anode at top. Samples 1, 3, 4, and 5 are juveniles; sample 2 is an adult. Electrophoretic conditions as in FIG. 1.

Wilkins — J. Fish. Res. Bd. Canada

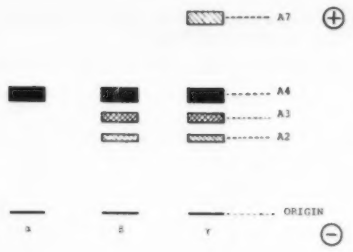


FIG. 3. Diagrammatic representation of three common patterns of the anodic haemoglobins of juvenile salmon. Fractions are numbered as in Fig. 1.

TABLE I. The length-distribution of three common patterns of anodic haemoglobins in juvenile salmon. The patterns α, β, and γ are illustrated diagrammatically in Fig. 3.

	Length (*cm*)																	
Pattern	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	No.	Mean length
α			1	–	3	2	–	–	–	1	1						8	10.375
β	1	3	5	3	6	3	5	6	10	8	14	4	2				70	12.042
γ								1	1	3	12	5	2	2	1	1	28	15.571
No.	1	3	6	3	9	5	5	7	11	12	27	9	4	2	1	1	106	12.848

Component A1 appears in fish above 20 cm fork length, and exhibits a gradual increase in concentration during subsequent growth.

Scottish and Canadian grilse exhibit a higher concentration than expected for their mean lengths.

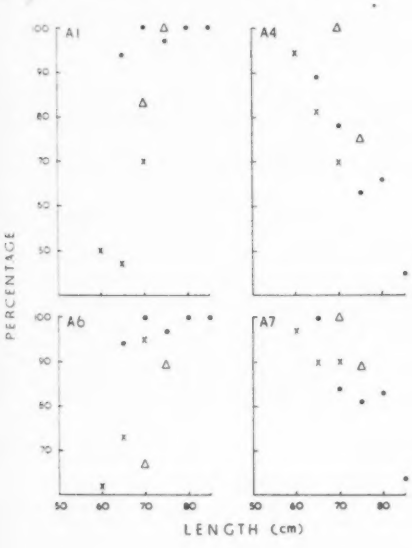


FIG. 4. The percentage of all individuals, at 5-cm intervals, in which fractions A1, A4, A6, and A7 are clearly detectable. × = Greenland adults, ● = Scottish adults, △ = Canadian adults.

TABLE II. Percentages of the total number of adult salmon in each sample completely lacking the various anodic haemoglobin fractions.

Hb fraction	Scottish adults	Greenland adults	Canadian adults
A1	1.9	47.8	4.5
A2	–	0.9	–
A3	0.6	3.5	–
A4	31.8	17.4	18.2
A5	–	–	–
A6	1.9	27.0	27.3
A7	17.5	8.7	4.5
A8	–	4.4	–
A9	1.9	9.6	–
No.	157	115	22
Mean length	77	66	76

COMPONENT A2

This appears early in juveniles, following A4 and A3. It is generally weak, but increases in concentration with increasing length.

In Scottish adults its concentration decreases significantly ($P < 0.01$) with increasing length. No such trend is evident in the Greenland material, which exhibits a lower concentration than the Scottish material. However, mean concentration in Scottish and Canadian grilse is close to that expected from Scottish adult data, and when all data are considered together, the trend to decreasing concentration with increasing length is evident.

This component, which appears early in the development of the haemoglobin pattern, apparently represents an "interim" component, increasing in concentration in early growth, and decreasing in large adults.

TABLE III. Observed percentage distribution, at 5-cm intervals, of the categories absent, weak, medium, and strong for fractions A4 and A6 in the Scottish and Greenland adult salmon samples.

Length (5-cm groups)	Fraction A4				Fraction A6				
	A	W	M	S	A	W	M	S	No.
Scotland									
65–69	11	45	33	11	6	22	44	28	18
70–74	22	59	13	6	–	12	28	59	32
75–79	37	43	18	2	3	10	25	62	60
80–84	34	46	20	–	–	14	31	51	35
85+>	55	45	–	–	–	-	44	56	11
Greenland									
60–64	6	53	29	12	38	35	24	3	34
65–69	19	58	17	7	27	42	20	10	59
70–74	30	60	5	5	5	35	45	15	20

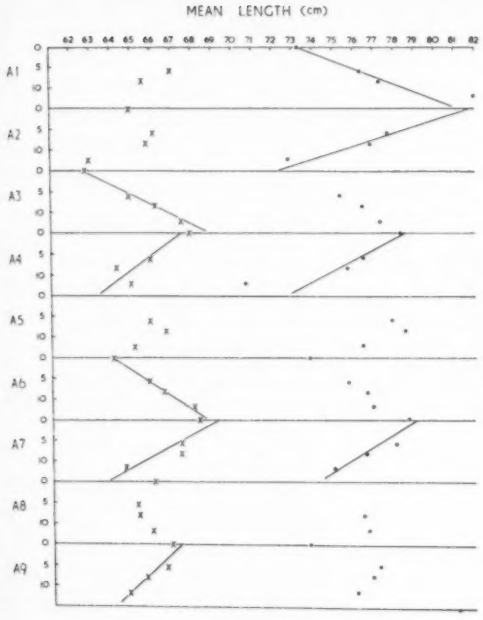


FIG. 5. The relation between mean length and concentration of the various haemoglobin fractions in Scottish and Greenland adult salmon. × = Greenland adults, ● = Scottish adults. Haemoglobin concentration is expressed on a scale of 0–12, in which 0 = absent, 5.7 = weakly present, 8.0 = intermediate concentration, and 12 = maximum concentration observed. Lines have been fitted where the regressions are significant.

COMPONENT A3

This appears very early in juveniles, at the same time as or soon after component A4. In both juveniles and adults, it exhibits increase in concentration with increasing length, tending to become very concentrated in large adults. This trend is significant in the Greenland material ($P < 0.001$). Although not significant in Scottish data, a similar trend is noticed; data for Greenland and Scotland plotted together (Fig. 6) suggest that increase in concentration with increasing length is real and continuous in both areas.

COMPONENT A4

Ontogenetically this is the most primitive haemoglobin, and is present at maximum intensity in even the smallest individuals. In adults, however, the concentration decreases significantly with increasing length ($P < 0.01$ in Scotland and Greenland), and it is absent in 36% of individuals over 85 cm and weakly present in a further 36%. It represents the major juvenile haemoglobin, and is present at high concentration in fish 50 cm long.

COMPONENT A5

This is not present in juveniles, but is present in medium or strong concentration in all adults. It appears and develops to high concentration during the period of growth from 20 to 50 cm long. There is no significant variation

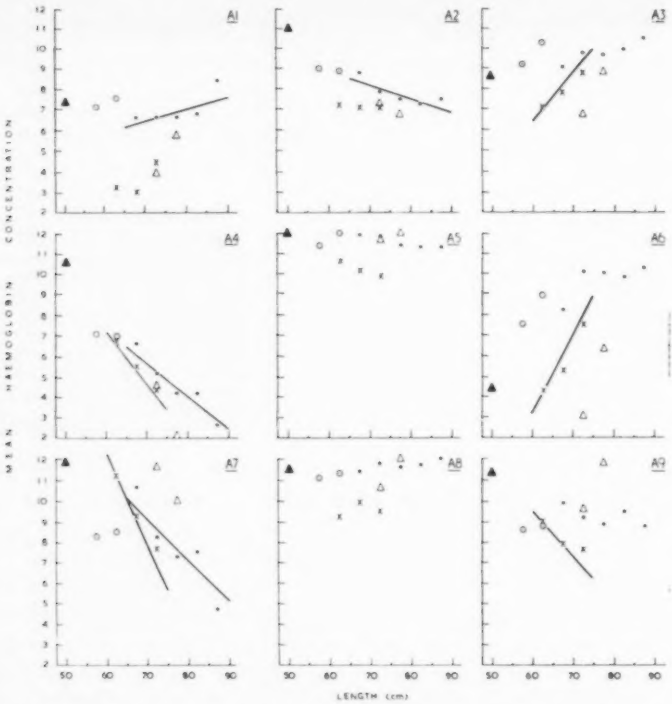


FIG. 6. The relation between mean haemoglobin concentration and length in all the salmon analysed. × = Greenland adults, ● = Scottish adults, ○ = Scottish grilse, △ = Canadian adults, ▲ = Canadian grilse. Lines have been fitted where the regressions are significant.

with length. Because of its constancy at lengths above 50 cm, it represents a major adult haemoglobin, in the same way as A4 is the major juvenile Hb, and A7 (see below) the major "prepuberal" Hb.

COMPONENT A6

This is not present in juveniles, and is absent in 33% of Canadian grilse (mean length 50 cm), and in 12% of Scottish grilse (mean length 60 cm). All individuals of 80 cm and over possess this component in high concentration. In Greenland and Scottish adults it increases in concentration with increasing length; the correlation is significant in the former ($P < 0.001$) but not in the latter.

COMPONENT A7

This is not present in the smallest individuals but appears at 11 cm and becomes more concentrated with increasing length. It was present at maximum

intensity in all but one Canadian grilse and in 31% of Scottish grilse. It exhibits a significant decrease in concentration with increasing length, in the Greenland ($P < 0.001$) and Scottish ($P <. 001$) material. It is completely absent in 36% of individuals of 85 cm and over. Component A7 is apparently an "interim" haemoglobin appearing relatively late in the juveniles, increasing during subsequent growth, and decreasing with further growth from 50 cm upwards.

COMPONENT A8

This is not present in juveniles. In adults, mean concentration tends to increase with increasing length, but not significantly in Greenland or Scottish data. The tendency is for increase in intensity with increasing length. The band is already present in individuals of 50 cm. Results for Scottish grilse and adults are in good agreement. In comparison with the Scottish fish the Greenland samples show a slightly lower than expected concentration of this component.

COMPONENT A9

This is not present in juveniles. In Greenland adults, a significant trend ($P < 0.05$) to decrease in concentration with greater length is observed. A similar trend, not significant, is evident in Scottish adults. Scottish grilse show values nearer to those of Greenland adults, whereas Canadian grilse results appear to lie in sequence with those of Scottish adults.

It can be seen that the complete pattern of the anodic haemoglobins tends, in the largest fish, to exhibit only five haemoglobin components, viz. Al, A3, A5, A6, and A8. Thus the complete ontogenetic development of the anodic haemoglobins proceeds from the single component (A4) in very small fish, through an intermediate phase in which nine components (A1-A9) are observed, to a pattern exhibiting five components (A1, A3, A5, A6, and A8). The cathodic components, which may be entirely absent in very small fish, proceed through a stage in which eight haemoglobin fractions are evident, to a pattern exhibiting five fractions. That is, no fewer than 17 haemoglobin fractions, of which only 10 subsist in large sexually mature fish, are observed in haemolysates of the salmon.

Investigations have been initiated to determine the molecular structure of the fractions. The reproducibility of the results, and the occurrence of repeatable variations in identically treated samples, exclude in vitro artefacts as an explanation of the observed phenomena. When samples are oxidised to methaemoglobin the entire electrophoretic pattern is more electro-positive, and, although the most anodic methaemoglobin fractions exhibit mobilities corresponding to certain of the least anodic unoxidised fractions, visual examination of unstained gels indicates that methaemoglobin is not present in normal fresh haemolysates.

When haemolysates were eluted through Sephadex G-200, the haemoglobin of adult salmon was recovered in an elution volume similar to that of

human haemoglobin, indicating a close similarity of molecular weight (ca 70,000) and the absence of larger (140,000 mol wt) haemoglobin polymers or aggregates in the haemolysates of the salmon. The observed relative elution volumes indicate that dissociation into subunits (Andrews, 1964) did not occur in the course of filtration. Electrophoresis of certain fractions in acid gels (Tris–citrate buffer, *p*H 2.0) with 2-mercaptoethanol reveals two major globin components in each fraction analysed, different fractions possessing different pairs of components. These investigations are not complete, but point strongly to the conclusion that fractions differ in one or more of their constituent polypeptide chains, and not in varying states of oxidation or of molecular aggregation.

DISCUSSION

It soon became evident (Wilkins, 1967) that the electropherograms differed in number of components observed and in ontogenetic variations from those obtained by Koch et al. (1964), which involved increase in anodic and cathodic components, with later reduction in the latter. In the present investigation, however, separation was sharper in the anode region, and the observed variations involve an initial increase and subsequent reduction in the numbers of anodic components.

Since neither the techniques nor the buffer systems used in these two studies were identical, co-operative experiments were carried out on the haemoglobins of Scottish and Scandinavian salmon with both electrophoretic methods and both buffer systems. The results have been published (Koch et al., 1967), but because of their relevance they are discussed here.

As a reversal of migration might occur when samples are analysed in different buffer systems, this possibility was explored by separating the anodic and cathodic groups of components on paper with Tris–HCl buffer. When the separated groups were exposed to electrophoresis in starch–gel with "Penny" buffer, no reversal of migration was observed. Conversely, when samples were allowed to separate a short distance to either side of the origin in a "Penny" starch–gel, and those portions of the gel containing the separated components were cut out and inserted in a suitably cut Tris–HCl gel, no reversal of migration was observed. Thus, with the two methods the total complement of haemoglobins is identical in the corresponding anodic and cathodic groups, and differences observed between corresponding groups must reflect partition differences within identical total complexes.

It follows that development of the anodic components described here is an extension of that already reported, and the complete ontogeny of salmon haemoglobins involves both the cathodic variations described by Koch et al. (1964) and the more extensive anodic variations described here.

Significant length-correlated variations in the appearance and disappearance of the various anodic components are detectable in salmon from each of the areas samples. For every component, the trend to increase or decrease is in the same direction for equivalent size ranges in each area, although the mean

concentration at a given length appears to differ for certain components. Scottish and Canadian adults, for instance, appear to differ significantly in mean concentration of components A6 and A7 in fish of 70–79 cm. These samples were obtained from sexually maturing fish in, or about to enter, rivers in Scotland and Canada respectively, and represent geographically isolated spawning populations. The observed differences suggest that relative rather than absolute size is important in haemoglobin development. This is in agreement with the results of Koch et al. (1964) on sea-going and landlocked populations of Scandinavian salmon. If rate of development of individual components, and thus of the complete pattern, is associated with relative length, i.e. with growth rate, it follows that different rates of development of the haemoglobin pattern may be characteristic of reproductively isolated stocks. As shown below, factors other than growth rate may also influence haemoglobin development.

The Greenland samples are derived from the feeding concentration of salmon in the vicinity of Godthåb on the west coast. Salmon in this area are known to be comprised of individuals of North American and European origin, with possibly a small proportion of locally spawning (Godthåb Fiord) fish. The Greenland salmon haemoglobin results are in good agreement with those obtained for Scottish and Canadian samples, and when the data from the three areas are considered together the trend for individual components to increase or decrease in intensity with change of length is sustained and even augmented. The close congruity of the results in the three areas would suggest that in the Greenland fishery no stocks other than those with haemoglobin developmental rates similar to those of Canada or Scotland are present to any appreciable extent.

In this context, the results for Scottish and Canadian grilse, which apparently do not recruit to the West Greenland fishery, are of interest. It has not been established that grilse differ genetically or are reproductively isolated from adult salmon of the same river, but they are phenotypically different in that they complete their first cycle of sexual maturation at least 1 year earlier. This represents a significant physiological difference, and for this reason the grilse data were treated separately.

The grilse results agree with the corresponding Scottish and Canadian adults for components A2, A4, A5, A6 (not for Canada) and A8, and the length-correlated variations of the other components in Scottish grilse and adults are in the same direction. Grilse, however, exhibit a lower than expected mean concentration of components A7 and A9 and a higher concentration of A1 and A3 (also of A6 in the Canadian material). As the development of these components appears to have progressed at a greater rate in the grilse, haemoglobin development may be independently regulated by factors which may or may not influence growth rate. Indeed, the observation that feeding with thyroid accelerates the differentiation of the haemoglobin pattern *independently of growth* (Koch et al., 1964), suggests that factors such as hormonal activity may play a significant role in the development of haemoglobin pattern.

The evidence supports the hypothesis that fractions differ in the primary structure of some, at least, of their constituent polypeptide chains, and consequently are coded by different structural genes. If salmon haemoglobins are symmetrical heteropolymers of two distinct polypeptide chains — as, for example, human Hb A ($\alpha_2^A \beta_4^A$) — then a minimum of 7 polypeptide chains is necessary to explain the occurrence of 17 (9 anodic and 8 cathodic) haemoglobin components. If, however, certain components represent homopolymers — as, for instance, human Hb H (β_4^A) — then six distinct polypeptides would satisfy. At the level of the genotype, then, six or seven structural genes may be coding for haemoglobin in this species. Since only one haemoglobin fraction may exist in very small fish, it is evident that polypeptide chain recombination cannot alone account for the regular appearance of all the fractions. The expression of the structural genes is obviously altering in a regular fashion throughout a great part of the life cycle, and factors governing this controlled expression, and their modes of action, are complex.

Feeding with thyroid has, for instance, been shown to accelerate haemoglobin development in juvenile salmon (Koch et al., 1964); in this respect the salmon resembles the frog, in which it has been shown (Moss and Ingram, 1965, 1968) that thyroxine stimulates the synthesis of adult haemoglobin polypeptide chains in unmetamorphosed tadpoles. Moss and Ingram (1965, 1968) and De Witt (1968) have postulated that the mode of action of the hormone involves suppression of the erythropoietic cell line synthesising tadpole haemoglobin, while stimulating the proliferation of a new cell line synthesising adult haemoglobin. The mode of action of administered thyroid tissue in salmon may be similarly indirect. However, the phenomena observed in the haemoglobin of salmon — and also in that of sea trout (Koch et al., 1964; N. P. Wilkins, unpublished results), herring (Wilkins and Iles, 1966), and sockeye salmon (Vanstone et al., 1964) — are notable in that they occur throughout the greater part of the life cycle, and are not restricted, as in most vertebrates, to easily identified, relatively short phases of metamorphosis or gestation.

ACKNOWLEDGMENTS

I wish to express my thanks to all those who assisted in supplying salmon blood for these studies, viz. Dr P. H. Odense of the Halifax Laboratory, Fisheries Research Board of Canada; the staffs of the M.A.F.F. Freshwater Laboratory, London, and D.A.F.S. Freshwater Laboratory, Pitlochry; to Messrs J. Møller Jensen and E. Hansen of the Grønlands Fiskeriundersogelser Laboratorium, Charlottenlund, Denmark; to The Berwick Salmon Fisheries Co. Ltd., Aberdeen Harbour Commissioners, and Messrs Jos. Johnston and Sons Ltd., Montrose, for supplying adult salmon from the rivers Tweed, Dee, and North Esk; to the proprietors and staff of the Invergarry Fish Hatchery and the Chorlo (New Brunswick) Hatchery for parr and smolts.

Greenland material was analysed at the Fiskerilaboratorium in Godthåb, Greenland. I thank Dr Paul Hansen, Director, Gronlands Fiskeriundersogelser,

for the excellent facilities provided. The Chromoscan was kindly provided by Dr G. Hobbs of Torry Research Station. Statistical analyses were performed by my colleague Mr W. B. Hall. Mr G. I. Sangster rendered invaluable technical assistance in collection of material and electrophoretic analyses.

REFERENCES

ANDREWS, P. 1964. Estimation of molecular weights of proteins by Sephadex gel filtration. Biochem. J., **91**: 222–233.

DE WITT, W. 1968. Microcytic response to thyroxine administration. J. Mol. Biol., **32**: 502–504.

FERGUSON, K. A., AND A. L. S. WALLACE. 1961. Starch-gel electrophoresis of anterior pituitary hormones. Nature, London, **190**: 629–630.

KOCH, H. J. A., EVA BERGSTROM, AND J. C. EVANS. 1964. The micro-electrophoretic separation on starch gel of the haemoglobins of *Salmo salar* L. Mededel. Koninkl. Vlaam. Acad. Wetenschap., **26**(9): 1–33.

1966. A size correlated shift in the proportions of the haemoglobin components of the Atlantic salmon (*Salmo salar* L.) and of the sea trout (*Salmo trutta* L.). Ibid., **28**(11): 1–20.

KOCH, H. J. A., N. P. WILKINS, EVA BERGSTROM, AND J. C. EVANS. 1967. Further studies on the multiple components of the haemoglobins of *Salmo salar* L. Ibid., **29**(7): 1–16.

MOSS, B., AND V. M. INGRAM. 1965. The repression and induction by thyroxine of haemoglobin synthesis during amphibian metamorphosis. Proc. Natl. Acad. Sci., **54**: 967–974.

1968. Haemoglobin synthesis during amphibian metamorphosis. II. Synthesis of adult haemoglobin following thyroxine administration. J. Mol. Biol., **32**: 493–502.

SCHUMANN, G. O. 1959. An electrophoretic survey of multiple haemoglobins in some fresh water fishes. Rept. Inst. Freshwater Res., Drottningholm, **40**: 176–197.

SMITHIES, O. 1959. An improved procedure for starch gel electrophoresis: further variation in the serum proteins of normal individuals. Biochem. J., **71**: 585–587.

VANSTONE, W. E., E. ROBERTS., AND H. TSUYUKI. 1964. Changes in multiple haemoglobin patterns of some Pacific salmon, genus *Oncorhynchus*, during the parr-smolt transformation. Canadian J. Physiol. Pharmacol., **42**: 697–703.

WILKINS, N. P. 1967. Immunology, serology and blood group research in fishes. *In* Polymorphismes biochemiques des animaux. Proc. 10th Congr. European Soc. Animal Blood Group Res., Paris, July 5-8, 1966. Inst. Natl. Rech. Agronom., Paris. p. 355–359.

WILKINS, N. P., AND T. D. ILES. 1966. Haemoglobin polymorphism and its ontogeny in herring (*Clupea harengus*) and sprat (*Sprattus sprattus*). Comp. Biochem. Physiol., **17**: 1141–1158.

Species Associations of Benthic Fishes on the Continental Shelf and Slope off Oregon[1]

By Donald S. Day

U.S. Bureau of Commercial Fisheries
Seattle, Washington

AND

William G. Pearcy

Department of Oceanography
Oregon State University, Corvallis, Ore., USA

ABSTRACT

Four species associations of benthic fishes found off the coast of Oregon within the depth interval from 40 to 1829 m were characterized by two or three most abundant species, depth range, and average sediment type.

Little overlap was found among species associations because many species had maximum abundance or were found only in one association. When a species occurred in more than one association, different sizes of fish were often found. Species on the lower continental slope had the broadest depth range, and a few species were found only in the deepest association.

Sixty-seven species of bottom fishes representing 21 families were collected, but 86% of the total number of fishes were from the families Pleuronectidae, Scorpaenidae, and Bothidae.

INTRODUCTION

Benthos are an important component of the marine ecosystem, and more information is needed on their ecology, species associations, and distributional patterns. This is particularly true in the northeastern Pacific Ocean, where international exploitation of fish stocks has increased much more rapidly than knowledge necessary for effective management of these fisheries (Alverson, et al., 1964).

Until recently, little was known about the depth distribution and species composition of benthic fishes inhabiting the northeastern Pacific Ocean. Grey (1956), for example, stated that no conclusions could be reached on the composition of the deepwater fishes of the eastern Pacific region, because little bottom fishing has been conducted in these waters since the *Albatross* cruises of the late nineteenth and early twentieth centuries.

Trawling surveys in recent years, mainly by the U.S. Bureau of Commercial Fisheries, have greatly increased knowledge about the distribution and abundance of demersal fishes of the northeastern Pacific (Alverson, 1953;

[1]Received for publication August 13, 1968.

J. Fish. Res. Bd. Canada, 25(12): 2665–2675, 1968.
Printed in Canada.

Hitz and Alverson, 1963; Alverson et al., 1964). Catch data from commercial trawlers have also been used to show seasonal variations in the catch patterns at various depths for some commercially important fishes (Alverson, 1960) and to show the species composition of the Oregon otter trawl fishery (Harry, MS, 1956).

The purpose of this study was to learn if species associations or assemblages of benthic fishes are obvious from an analysis of catch data off the central Oregon coast and, if associations are apparent, to learn how they are related to bottom sediment type and depth of water. This paper is based on a survey of benthic fishes at depths from 40 to 1829 m on the continental shelf and slope off the central coast of Oregon. The continental terrace off Oregon is narrow and steep, extending to 106–109 km from shore (Byrne, 1962; Shepard, 1948). This feature permitted sampling a wide range of depths and sediment types on the shelf and slope within a short distance from shore.

METHODS

Benthic fishes were sampled with a semi-balloon shrimp trawl (Greenwood, 1959). The headrope of the trawl was 6.7 m long and the footrope 8.2 m long. The net was constructed from 32-mm (stretch measured) cotton netting of number 18 thread. Either wood or metal otter doors were used to spread the trawl.

All tows were made with the single warp method in which a bridle, composed of two 30-m legs of braided nylon rope, connected the otter doors and net to the 9.5-mm towing cable.

The trawl was set and retrieved while the ship was underway at low speeds, and towed at a speed of approximately 3 knots. The duration of each tow, estimated from the time the maximum amount of cable was in the water to the beginning of retrieval, was 20 min where the depth was 274 m or less, and 30–60 min where the bottom was deeper. The amount of cable required to trawl on the bottom was established by trial. A 4:1 to 6:1 ratio of wire length to water depth was used for the stations inshore of the 366-m contour and 2.5:1 or 3:1 for deeper stations. These ratios are similar to those given by Pereyra (1963) for a 13.1-m flat shrimp trawl.

In all, 36 samples were collected off the central Oregon coast from Cape Foulweather to Waldport at depths from 40 to 1829 m (Fig. 1) between July 1961 and June 1962. Fourteen samples were obtained over the shelf (146 m or less) and 22 samples on the slope (146–1829 m).

Station positions were determined primarily by Loran with radar and echo-sounding equipment as supplementary navigational aids. A Precision Depth Recorder in conjunction with an Edo Echo Sounder was used to determine depth and suitable bottom topography. Tows were usually made over comparatively flat terrain parallel to the bottom contour lines. Nevertheless, the trawl was torn or lost during 6 of 12 unsuccessful tows, evidence of the roughness of the bottom in this area. The main obstruction to bottom trawling on the shelf was a region of rock out-cropping known as Stonewall

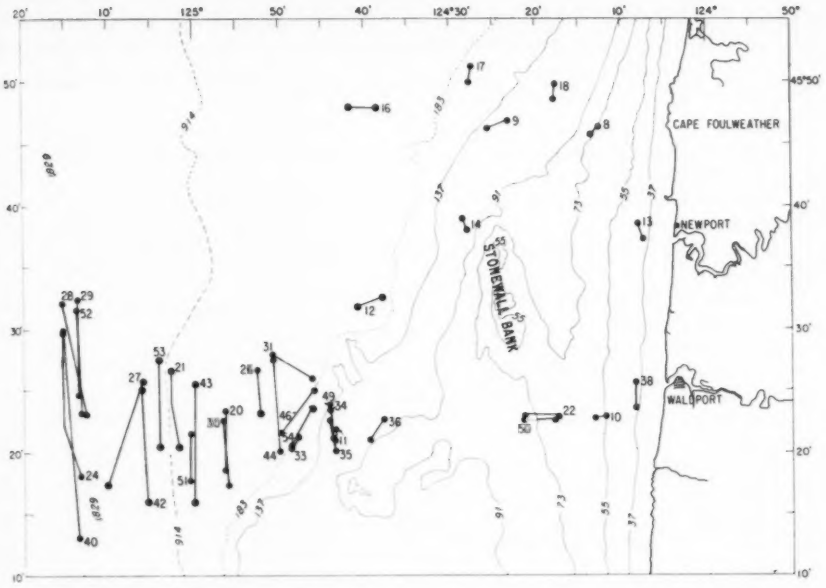


FIG. 1. Location of trawling stations off the central coast of Oregon. The length of the lines indicates the total distance of the tow, including ascent and descent of the trawl.

Bank (Fig. 1). Sampling locations on the shelf were usually on the periphery of this rock formation.

Benthic fishes in the samples were sorted into taxonomic groups and the most abundant species were identified and measured (total length) at sea. The remaining fish were preserved in 10% formalin at sea and identified and measured ashore.

A Dietz-LaFond sampler was used to collect sediment from the continental shelf, and a Phleger corer with a 300-mm sample tube was used on the slope. Sediment samples were collected at each trawl station for particle-size analyses. Hydrometric and settling tube methods were used to determine the percentage composition of sand, silt, and clay (Wentworth scale).

RESULTS

SPECIES COMPOSITION

A total of 7689 fishes representing 21 families and 67 identified species was collected during this study (Table I). Most of these fishes are considered to be benthic or demersal, although some are pelagic and swim just above the bottom; others may migrate vertically and occur near the bottom only during daytime. Midwater fishes, mainly mesopelagic species (see Pearcy, 1964), were collected as the net descended or ascended through the water column but are not included.

TABLE I. List of benthic fishes collected off the central coast of Oregon during this study.

Families and species	Families and species
Myxinidae	*Sebastodes helvomaculatus* (Ayres) 1859
Eptatretus deani (Evermann and Goldsborough) 1906	*Sebastodes melanops* (Girard) 1856
Eptatretus stoutii (Lockington) 1878	*Sebastodes proriger* (Jordan and Gilbert) 1880
Squalidae	*Sebastodes saxicola* (Gilbert) 1890
Squalus acanthias Linnaeus 1758	*Sebastodes wilsoni* Gilbert 1915
Rajidae	*Sebastodes zacentrus* (Gilbert) 1890
Psammobatis spinosissimus Beebe and Tee-Van 1941	Hexagrammidae
Raja binoculata Girard 1854	*Ophiodon elongatus* Girard 1854
Raja kincaidii Garman 1908	Anoplopomatidae
Raja rhina Jordan and Gilbert 1880	*Anoplopoma fimbria* (Pallas) 1811
Raja trachura Gilbert 1891	Cottidae
Chimaeridae	*Chitonotus pugetensis* (Steindachner) 1877
Hydrolagus colliei (Lay and Bennett) 1839	*Hemilepidotus spinosus* (Ayres) 1855
Alepocephalidae	*Icelinus filamentosus* Gilbert 1890
Alepocephalus convexifrons Garman 1899	*Icelinus tenuis* Gilbert 1890
Moridae	*Paricelinus hopliticus* Eigenmann and Eigenmann 1889
Antimora rostrata Gunther 1878	*Radulinus asprellus* Gilbert 1890
Gadidae	Bothidae
Microgadus proximus (Girard) 1854	*Citharichthys sordidus* (Girard) 1854
Macrouridae	*Citharichthys stigmaeus* Jordan and Gilbert 1882
Coryphaenoides acrolepis (Bean) 1883	Pleuronectidae
Coryphaenoides pectoralis (Gilbert) 1891	*Atheresthes stomias* (Jordan and Gilbert) 1880
Embiotocidae	*Embassichthys bathybius* (Gilbert) 1890
Cymatogaster aggregata Gibbons 1854	*Eopsetta jordani* (Lockington) 1879
Bathymasteridae	*Glyptocephalus zachirus* Lockington 1879
Ronquilus jordani (Gilbert) 1888	*Isopsetta isolepis* (Lockington) 1880
Stichaeidae	*Lepidopsetta bilineata* (Ayres) 1855
Plectobranchus evides Gilbert 1890	*Lyopsetta exilis* (Jordan and Gilbert) 1880
Zoarcidae	*Microstomus pacificus* (Lockington) 1879
Aprodon cortezianus Gilbert 1890	*Parophrys vetulus* Girard 1854
Bothrocara brunneum (Bean) 1890	*Platichthys stellatus* (Pallas) 1811
Bothrocara remigera Gilbert 1915	*Pleuronichthys decurrens* Jordan and Gilbert 1880
Embryx crotalina (Gilbert) 1890	Agonidae
Lycodes diapterus Gilbert 1891	*Agonopsis emmelane* (Jordan and Starks) 1895
Lycodopsis pacifica Collett 1879	*Asterotheca infraspinata* (Gilbert) 1904
Brotulidae	*Asterotheca pentacantha* (Gilbert) 1890
Cataetyx rubrirostris Gilbert 1890	*Bathyagonus nigripinnis* Gilbert 1890
Scorpaenidae	*Occa verrucosa* (Lockington) 1880
Sebastolobus alascanus Bean 1890	*Xeneretmus latifrons* (Gilbert) 1890
Sebastolobus altivelis Gilbert 1893	*Xeneretmus triacanthus* (Gilbert) 1890
Sebastolobus spp.	Liparidae
Sebastodes alutus (Gilbert) 1890	*Careproctus melanurus* Gilbert 1891
Sebastodes crameri Jordan 1896	*Rhinoliparis attenuatus* Burke 1912
Sebastodes diploproa (Gilbert) 1890	
Sebastodes elongatus (Ayres) 1859	
Sebastodes entomelas (Jordan and Gilbert) 1880	

Pleuronectidae, Scorpaenidae, and Bothidae were clearly the dominant families. They comprised approximately 86% of the total number of specimens in the catch. Numerically abundant species for each of these families were:

	% of catch within family
Pleuronectidae	
Lyopsetta exilis	68
Glyptocephalus zachirus	14
Parophrys vetulus	9
Microstomus pacificus	5
Total	96
Scorpaenidae	
Sebastolobus altivelis	54
Sebastolobus alascanus	34
Total	88
Bothidae	
Citharichthys sordidus	97

Families contributing the most species were: Scorpaenidae (13 species), Pleuronectidae (11), Agonidae (7), Cottidae (6), Zoarcidae (6), and Rajidae (5).

Species associations, or groups of species commonly found living together, were revealed by comparing indices of similarity among all collections (e.g., Wieser, 1960; MacFadyen, 1963). The percentage composition was computed for all species in each sample, and all possible sample pairs were compared. For each species common to both samples, the lower of the two percentage composition values was taken as a measure of species association between the two samples. The sum of these low values then provides an index of similarity for the two samples. For example, if species X, Y, and Z occurred in samples I and II at the following percentages:

	Sample I (%)	*Sample II (%)*
Species X	10	50
Species Y	75	20
Species Z	15	30

then the index of similarity is 45% for these two samples. Finally, we arranged the values obtained from all possible combinations of samples in a trellis diagram to show the relations among samples.

This trellis diagram (Fig. 2) shows the degree of similarity for samples of benthic fishes collected with increasing depth across the continental shelf and slope. Three benthic fish associations are obvious. Note the clusters of samples of high similarity (>50%) separated by regions of low similarity (<29.9%). In the region of deepest sampling a fourth association is suggested.

The dominant species, depth intervals, and average sediment types for these associations, designated as species-groups I, II, III, and IV, are given in Table II. Dominance is pronounced. Only two or three species contributed

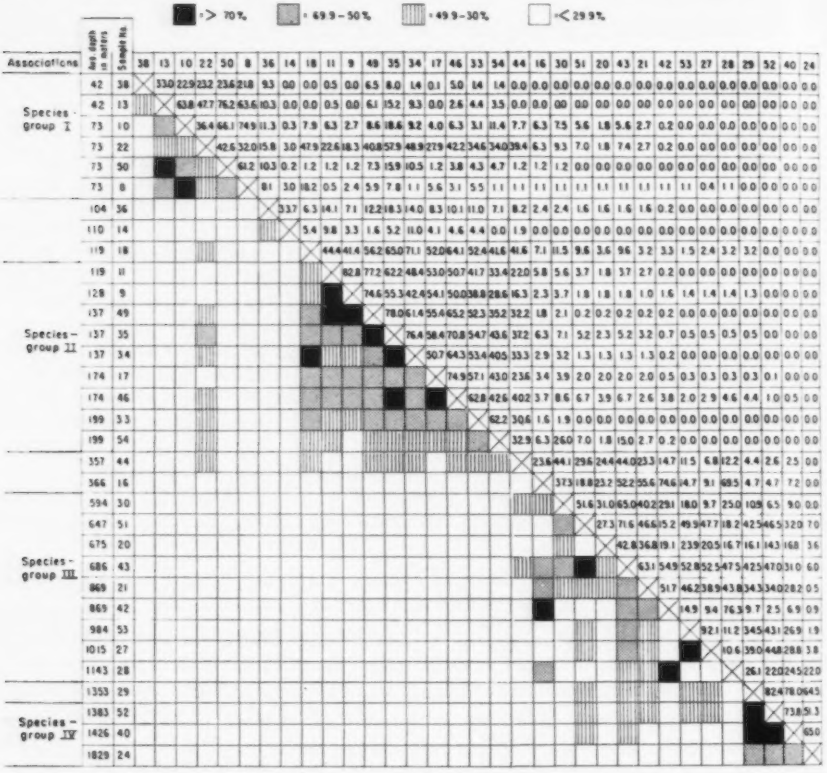


FIG. 2. "Trellis Diagram" illustrating the degree of similarity of the benthic fish fauna at the stations on the shelf and slope off the central coast of Oregon.

from 77 to 93% (by number) of the fish fauna in each association. Also, the depth interval and sediment type associated with each species-group are different.

Although not apparent from Fig. 2, the association represented by species-group IV is distinct, based on changes in species composition. Deepwater species, *Coryphaenoides acrolepis* and *Antimora rostrata*, were dominant in these catches, whereas *Sebastolobus altivelis* and *S. alascanus* decreased relative to species-group III.

Almost one-half the total number of species of benthic fishes was found only in one association. Species limited to one association comprised 50% of the species in group I, 48% in group II, 47% in group III, and 22% in group IV. Thus the degree of fidelity, or restriction to one association, remained approximately constant with increasing depth through species-group III but decreased rapidly with group IV. This trend for deeper species to have a broader depth range is also illustrated in Fig. 3.

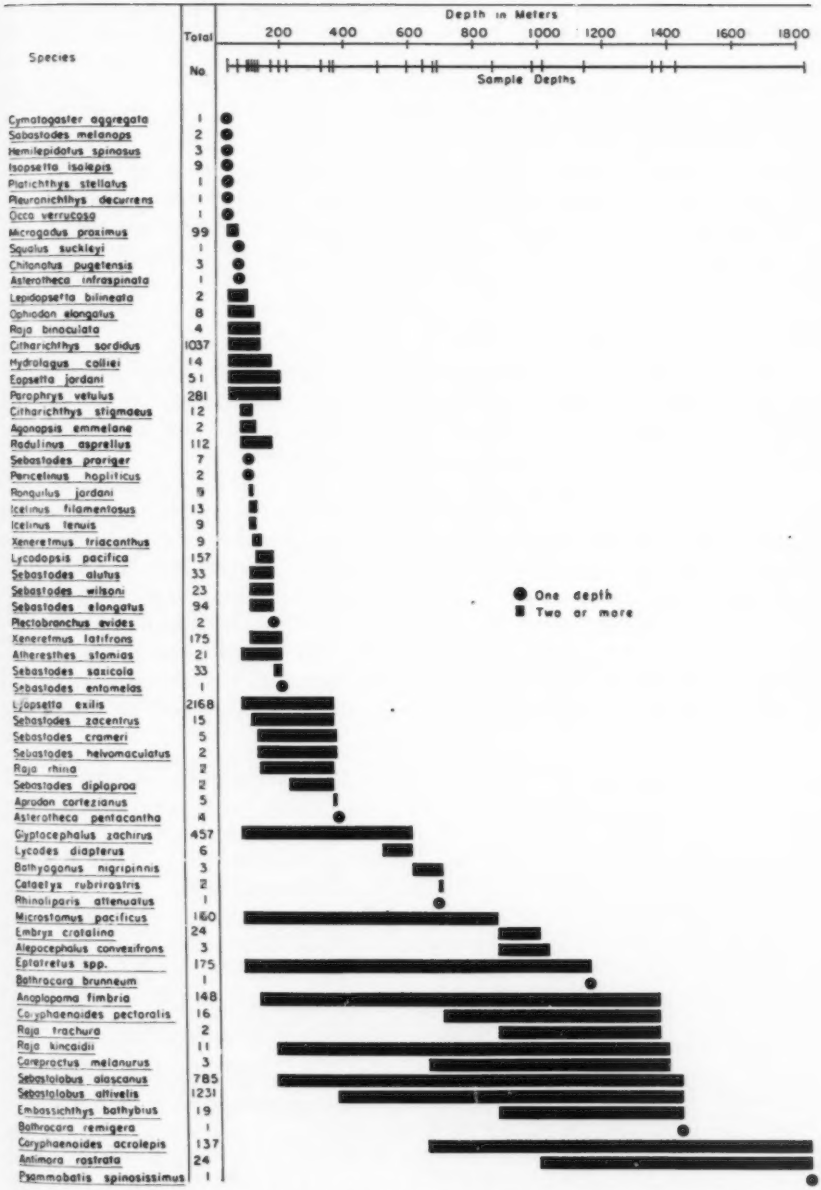


FIG. 3. Depth ranges for species of benthic fishes collected off the central coast of Oregon. (*Squalus suckleyi should be replaced with Squalus acanthias.*)

Other species were found in two or more associations, but these were usually much more abundant in one species-group than in any other, and 88% of the species exhibited high abundance (>60% of total number) in only one particular association. When species were found in more than one association, moreover, individuals of different sizes were often found in different associations. The average size of *Parophrys vetulus*, *Citharichthys sordidus*, *Eopsetta jordani*, *Microstomus pacificus*, and *Anoplopoma fimbria* increased in species-groups found in progressively deeper water. Thus overlap of the associations was small, since species generally were associated with only one species-group, or showed high abundance in one particular species-group, or were segregated by size.

Associations and Sediment Type

The sediment texture varied from 100% sand on the upper shelf to a silty clay on the lower slope. Usually the average sediment type was different for each species association of fishes (Tables II and III), a relation previously described for benthic invertebrates (e.g. Thorson, 1955).

Sometimes species-groups and sediment types did not coincide exactly. For example, two distinct sediment types were found in the depth range of species-groups II and III, where finer sediments were collected at the deepest stations (Table III). This lack of correspondence suggests that faunal similarities are maintained in regions of sediment transition, and conversely, that factors other than sediment may govern the distribution of associations. We should be cautious in our interpretations, however. Because of the variability of sediments particularly on the upper slope and lower shelf (see Table III) the sediment sampled and the sediment trawled over could be different.

Table II. Depth interval, average sediment type, and dominant species for each species-group.

Species associations	Depth interval (*m*)	Avg sediment type for each species association (%)	Dominant species	% composition
I	42–73	100 sand	*Citharichthys sordidus*	64.0
			Parophrys vetulus	16.3
			Total	80.3
II	119–199	69 sand,	*Lyopsetta exilis*	66.4
		19 silt,	*Glyptocephalus zachirus*	11.4
		12 clay	Total	77.8
III	594–1143	17 sand,	*Sebastolobus altivelis*	49.7
		55 silt,	*Sebastolobus alascanus*	30.9
		28 clay	Total	80.6
IV	1383–1829	1 sand,	*Coryphaenoides acrolepis*	51.6
		53 silt,	*Sebastolobus altivelis*	26.3
		46 clay	*Antimora rostrata*	14.7
			Total	92.6

TABLE III. Sediment composition at each biological sampling location, and average sediment composition with respect to depth and the benthic fish associations.

Species-groups	Sample no.	Avg depth (*m*)	Sediment composition (%)				Avg sediment composition (%)
			Rock	Sand	Silt	Clay	
I	38	42		100			100 sand
	13	42		100			
	10	73		100			
	22	73		100			
	50	73		100			
	8	73		100			
	36	104	100				Rock
II	14	110		65	19	16	81 sand, 10 silt, 9 clay
	18	119		88	5	7	
	11	119		89	5	6	
	9	128		73	10	17	
	49	137		89	5	6	
	35	137		89	5	6	
	34	137		89	5	6	
	17	174		56	25	19	
	46	174		87	11	2	
III	33	199		23	53	24	28 sand, 48 silt, 24 clay
	54	199		23	53	24	
	12	221		47	28	25	
	31	329		53	31	16	
	44	357		23	53	24	
	16	366		52	20	28	
	26	508		38	48	14	
	30	594		14	64	22	
	51	647		28	58	14	
	20	675		14	64	22	
	43	686		28	58	14	
	21	887		20	42	38	
	42	887		3	56	41	
	53	984		35	45	20	
	27	1,015		12	54	34	
IV	28	1,143		1	51	48	1 sand, 53 silt, 46 clay
	29	1,353		1	54	45	
	52	1,383		1	54	45	
	40	1,426		1	51	48	
	24	1,829		2	53	45	

DEPTH DISTRIBUTIONS

Figure 3 shows the depth distributions of the species collected. The depth ranges of species found on the shelf are clearly less than the ranges of species found on the slope. Some species, such as *Glyptocephalus zachirus* and *Microstomus pacificus* range from shelf waters deep into the slope waters.

Forty-two species occurred on the continental shelf; 43 occurred on the continental slope; thus, the total number of species was about the same. The

total number of species collected in each association was 26 in group I, 31 in group II, 19 in group III, and only 9 in group IV.

DISCUSSION

Sampling bias is an inherent problem in any study of natural populations, such as benthic fishes. A portion of the benthic fishes along a given path will avoid or escape any net. Thus only a partial estimate of the benthic fish populations can be obtained by the use of one type of sampling equipment.

That the catch composition will be different in different types of trawls is shown by comparing our results with those obtained by Alverson et al. (1964). They used a larger net (28.7-m eastern fish trawl) and larger mesh (89–137 mm stretch) than our shrimp trawl and towed with a double rather than a single warp. As expected, the shrimp trawl retained smaller sizes of fishes than the larger fish trawl (Jurkovich, 1954; Pereyra et al., 1967). Also, the relative abundance of some species was grossly different in the two studies. Whereas Alverson et al. (1964) reported 22 species of rockfishes and 14 flatfishes off Oregon and Washington, we collected only 12 rockfishes and 13 flatfishes. *Sebastodes elongatus*, our most abundant rockfish species, was not significant in their rockfish catches off Oregon. Conversely, *Sebastodes alutus*, *Merluccius productus*, and *Squalus acanthias* were important species in their catches but were only rare or absent in our survey. Thus, the 6.7-m shrimp trawl apparently did not retain large demersal species or species which are more nektonic and may range off the bottom.

The differences between the studies may be accentuated by the fact that Alverson et al. (1964) sampled extensively off both Oregon and Washington, whereas our study was confined to a small area. By summarizing their catches over a large geographic area, they combined associations found on different sediment types, possibly explaining in part why dominant species within various depth intervals were different in the two studies.

Perhaps the combined results of both studies would provide a more accurate average picture of the benthic fish associations off Oregon. Unfortunately, there is no basis for combination; the collections were made in different areas, and Alverson et al. (1964) ranked their species by weight instead of numbers. As a result, it is not known whether the larger, more nektonic fishes, such as rockfishes and hake, are closely associated with our species-groups. Since they are more pelagic in their ecology, it may be expected that depth and sediment type are not as important to the distribution of these species as they are to the benthic species.

ACKNOWLEDGMENTS

This study was supported by the U.S. Atomic Energy Commission, Contract No. AT(45-1)1726. The junior author was supported in part by the National Science Foundation Institutional Sea Grant GH-10.

REFERENCES

ALVERSON, DAYTON L. 1953. Deep-water trawling survey off the Oregon and Washington coasts. Com. Fish. Rev., **15**(10): 5–15.

1960. A study of annual and seasonal bathymetric catch patterns for commercially important ground-fishes of the Pacific northwest coast of North America. Pacific Marine Fish. Comm. Bull. No. 4. 66 p.

ALVERSON, D. L., A. T. PRUTER, AND L. L. RONHOLT. 1964. A study of demersal fishes and fisheries of the Northeastern Pacific Ocean. H. R. MacMillan lectures in fisheries. Univ. British Columbia, Vancouver, B.C. 190 p.

BYRNE, JOHN V. 1962. Geomorphology of the continental terrace off the central coast of Oregon. The Ore Bin, **24**(5): 65–74.

GREENWOOD, MELVIN R. 1959. Shrimp exploration in central Alaskan waters by M.V. *John N. Cobb*, July–August 1958. Com. Fish. Rev., **21**(7): 1–13.

GREY, MARION. 1956. The distribution of fishes found below a depth of 2000 meters. Fieldiana Zool., **36**: 5–337.

HARRY, GEORGE YOST. MS, 1956. Analysis and history of the Oregon otter-trawl fishery. Ph.D. Thesis. University of Washington, Seattle, Wash. 329 p.

HITZ, C. R., AND D. L. ALVERSON. 1963. Bottom fish survey off the Oregon coast, April–June 1961. Com. Fish. Rev., **25**(6): 1–7.

JURKOVICH, JERRY. 1954. Selectivity of cod-end mesh sizes in otter trawling. Fish. Res. Papers, **1**(2): 19–24.

MACFADYEN, A. 1963. Animal ecology. 2d ed. Pitman, New York. 344 p.

PEARCY, W. G. 1964. Some distributional features of mesopelagic fishes off Oregon. J. Marine Res., **22**(1): 83–102.

PEREYRA, WALTER T. 1963. Scope ratio-depth relationships for beam trawl, shrimp trawl, and otter trawl. Com. Fish. Rev., **25**(12): 7–10.

PEREYRA, WALTER T., HIROMU HEYAMOTO, AND ROBERT R. SIMPSON. 1967. Relative catching efficiency of a 70-foot semi balloon shrimp trawl and a 94-foot Eastern fish trawl. U.S. Fish Wildlife Serv., Fish. Ind. Res., **4**(1): 49–71.

SHEPARD, F. P. 1948. Submarine geology. Harper and Brothers, New York. 348 p.

THORSON, G. 1955. Modern aspects of marine level-bottom animal communities. J. Marine Res., **14**: 387–397.

WIESER, WOLFGANG. 1960. Benthic studies in Buzzards Bay. II. The meiofauna. Limnol. Oceanog., **5**: 121–137.

Effect of Sublethal DDT on the Lateral Line of Brook Trout, *Salvelinus fontinalis*[1]

By John M. Anderson[2]

Department of Biology
Carleton University, Ottawa, Ont.

ABSTRACT

The lateral line nerve of brook trout responds to an abrupt low-frequency pressure wave, generated by a falling drop of water hitting the water surface, by a relatively short high-frequency burst of large spikes. The burst duration has a negative temperature coefficient. Exposure of trout for 24 hr to DDT, ranging from 0.1 to 0.3 ppm, renders the lateral line nerve hypersensitive to the experimental stimulus; in particular there is a marked increase, especially at the colder temperatures, in the negativity of the temperature coefficient of the burst durations. The results are discussed in general terms, as well as specifically in relation to other laboratory work which shows that sublethal DDT affects behavioural responses of fish to temperature.

INTRODUCTION

The chlorinated hydrocarbon insecticide DDT is well known to affect nervous tissue, both central and peripheral. Little work, however, has been done on fish. This paper reports on some effects of 24-hr exposure to sublethal amounts of DDT on the neurophysiological functioning of the trunk lateral line nerve of brook trout, *Salvelinus fontinalis* (Mitchill).

MATERIALS AND METHODS

The brook trout were yearlings averaging 15.2 cm (6 inches) long and 36 g in weight. For at least a month before use the fish had been acclimated to 21.5 ± 0.5 C and subjected to a light regime of 12 hr light – 12 hr dark. The experiments were done in August 1966. Treated fish were exposed for 24 hr to DDT at a concentration of either 0.1, 0.2, or 0.3 parts per million (ppm). DDT exposure was carried out in glass jars containing 5 liters of water at the acclimation temperature. The DDT was added to the water in 0.5 ml of acetone. One fish was used per exposure jar. Control fish were similarly treated except that the 0.5 ml of acetone contained no dissolved DDT.

In preparation for the electrophysiological work, the fish were first stunned with an electric shock and then pithed by running a dissecting needle through the hind brain and then rotating the needle vigorously latero-anteriorly. A small flap of skin about 1.5 cm long, just posterior to the operculum, was freed by making two longitudinal incisions about 0.5 cm above and below the lateral line canal. These incisions were connected at their anterior ends

[1]Received for publication June 24, 1968.
[2]Present address: Fisheries Research Board of Canada, Biological Station, St. Andrews, N.B.

J. Fish. Res. Bd. Canada, 25(12): 2677–2682, 1968.
Printed in Canada.

by a vertical cut which just penetrated the skin. The skin was then carefully peeled back with forceps. The section of the lateral line nerve of the vagus thereby exposed was freed from surrounding tissues with fine glass hooks (taking care not to exert a pulling force which would damage the neuromasts posterior to the cut), tied off with thread as far forward as possible, and then cut on the central side of the ligature. The fish, pinned to a sloping wax block, was then placed in a plastic water bath, 18 × 30 × 8 cm deep, so that all of the body posterior to the operated area was under water. A drain in the bottom of the box, together with separate cold- and warm-water inlets, permitted the water temperature to be changed to any desired level within a few seconds.

The stimulus for the lateral line was the disturbance generated by a drop of water, 4 mm in diam, falling from a height of 12.7 cm (5 inches) from the end of a 25-ml burette. The drop struck the surface of the water directly over the lateral line canal and about midway along its length. At this point the depth of water over the skin was about 4.8 cm (1½ inches). The response to the stimulus was picked up by fine silver–silver chloride electrodes. The nerve was draped over one electrode; the indifferent electrode was inserted into the tissue near the recording site. The amplifier was a Grass model P5. Some of the responses were recorded as they happened by a polaroid camera, using an arrangement by which the falling drop triggered the oscilloscope (Tetronix 502A). For the most part, however, the responses were too long to be included in their entirety on one sweep. The most satisfactory read-out system used was a Model PI-6100 Precision Instrument tape recorder using FM recording at 3.75 inches per sec. A motion picture oscilloscope camera provided a permanent record of some of the replays but, for purposes of determining the duration of the response (with which this report is primarily concerned), a much faster method (with no loss in accuracy) was to feed the tape signal at $\frac{1}{10}$ its original speed into the 7P5 preamplifier module of a Grass Model 7 Polygraph running at 10 mm per sec.

Some of the characteristics of the stimulus were determined by filling the test tank with water to the usual depth and installing a hydrophone with its sensing surface at the approximate location of the lateral line directly below where the falling drop struck the surface of the water during the experiments. The falling drop produced a pressure wave of about 38 Hz which at the point of the hydrophone measured approximately 40 dynes per cm^2.

RESULTS

The multifibre response of the lateral line to the disturbance generated by the falling drop of water consisted of a train or burst of relatively large spikes which were clearly distinguishable from the spontaneous activity. In Fig. 1 are shown typical results for an untreated fish tested at 5 and 14 C (*a* and *b*, respectively). The bursts are of relatively short duration (.05 sec at 5 C; .02 sec at 14 C) with a frequency of approximately 400 impulses per sec. DDT-treatment (Fig. 1, *c* and *d*) results in a marked prolongation of the

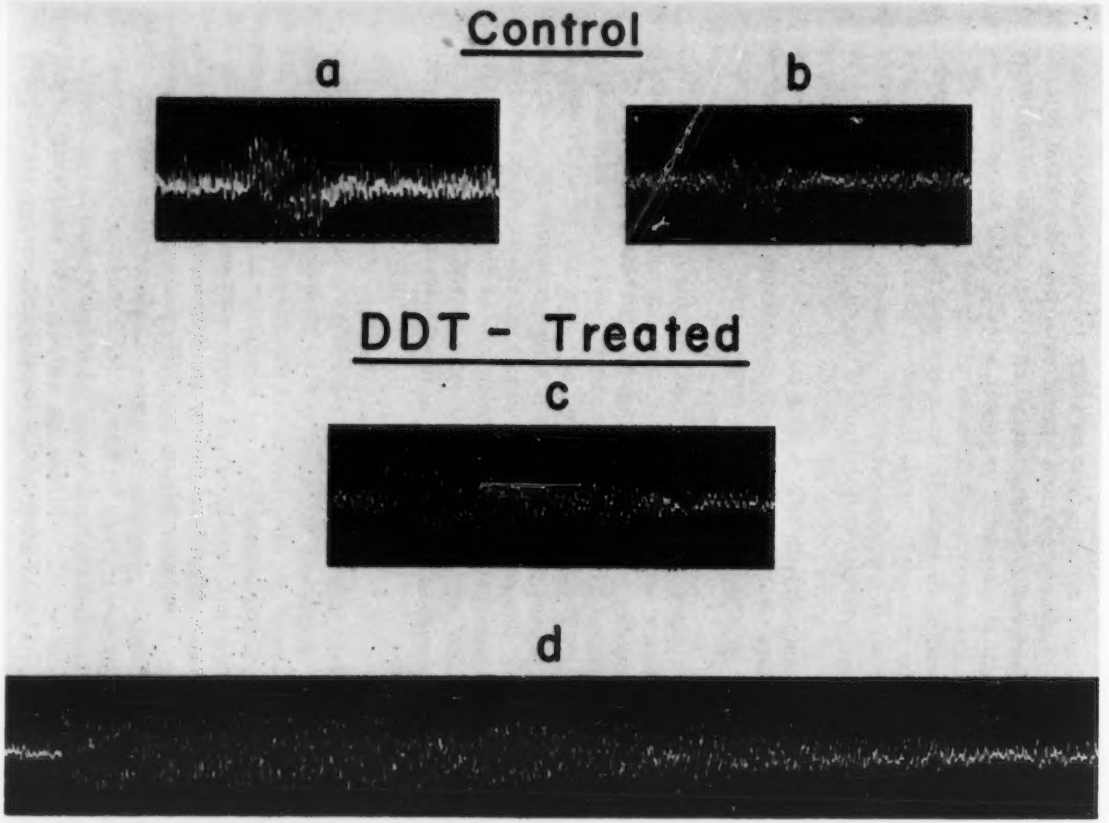


FIG. 1. Typical multifibre response of lateral line nerve of brook trout to the disturbance generated by a falling drop of water hitting the water surface. Control: *a*, 5 C; *b*, 14 C. DDT-treated (0.2 ppm): *c*, 13 C; *d*, 4 C.

Anderson — J. Fish. Res. Bd. Canada

response with this potentiating effect appearing much more pronounced at the colder temperature. Initially the frequency is about the same as for the controls, with large spikes predominating. With time there is a progressive and gradual disappearance of spikes according to size, the larger ones going first, until finally the discharge blends into the spontaneous activity characteristic of the resting nerve. As far as could be determined from inspection of all records, the DDT-affected responses differ only in their duration.

The relation between the duration of the response and test temperature is shown in Fig. 2. Each fish was tested at about six different temperatures and each point plotted is the average of about 10 separate trials at each temperature. The results represent 10 treated fish and 9 control fish (several other fish were tried but no electrophysiological activity could be obtained). The general procedure was to change the temperature by abrupt steps of a few degrees, in one direction at a time. The direction was about as often downwards as it was upwards on the temperature scale and as far as could be determined neither the direction nor the magnitude of the temperature changes had any influence on the results.

Although the variability of the results is clearly great, a general pattern emerges. For control fish the duration of the response is somewhat less than 0.05 sec at high temperatures and appears to increase gradually to somewhat more than 0.10 sec at low temperatures. The DDT-treated fish show the same general trend, but with two notable differences. First, the response is longer at all test temperatures; and second, the increase in the duration of the response at the colder temperatures is proportionately much greater, i.e. the DDT effect has a much more pronounced negative temperature coefficient. There is a suggestion, but no more than that, that the DDT response, particularly at the colder temperatures, is concentration-dependent.

DISCUSSION

Evidently not all of the fibres are firing in the resting state. The adequate stimulus in these experiments for the quiescent neuromasts apparently is a sudden "noise." These results are consistent with the work of Katsuki and Yoshino (1952) where it was shown for the Japanese eel, *Anguilla japonica*, that although fibre diameter varied in the lateral line nerve continuously (from 4 to 15 μ), physiological action did not. Spontaneous discharge was a property of the thin fibres. The end organs innervated by them adapted slowly and had only moderate maximum discharge frequencies (about 40 impulses per sec). The thick fibres showed no spontaneous activity, and their end organs adapted rapidly and had a higher threshold and maximum discharge frequency (more than 100 impulses per sec).

Whether the provocative part of the stimulus used in the present work is the compression wave, or the water displacement which is always associated with a compression wave, or a combination of both, cannot be determined from our results. I have calculated, having assumed that the water drop would penetrate the water about one half the distance (2 mm) of its diameter before

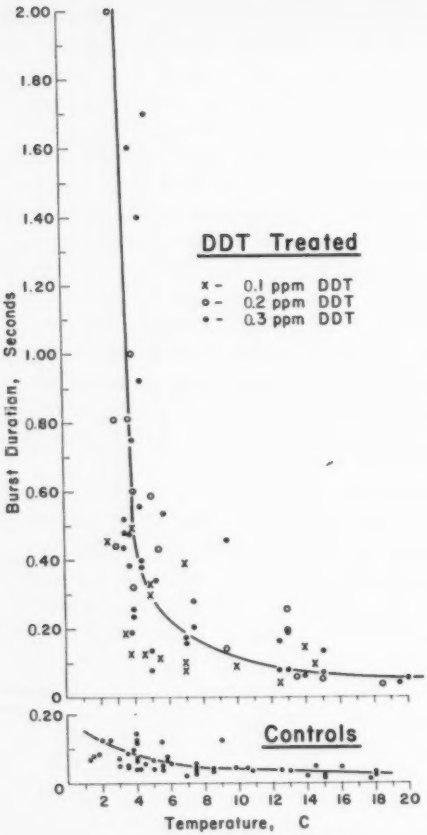


FIG. 2. Relation between duration of response of lateral line to experimental stimulus and test temperature for control and DDT-treated brook trout.

stopping, that the water displacement as a function of the near-field effect would be about 3000 A° at the lateral line. It is assumed that this displacement would predominate over the far-field compressional effect, which in our case would be about 100 A°. There is, however, no evidence that the central nervous system makes any use of the information which the sense cells provide in response to near-field displacements in these experiments. One can argue that, in nature, near-field effects almost certainly occur (caused by, for example, the movement of nearby fish in a school) and that it would seem unlikely that the central nervous system (CNS) could simply ignore the trains of afferent impulses thereby generated. However, vision, and to a lesser extent odours, appear to be the operative stimuli in schooling (Keenleyside, 1955). There seems no doubt that the CNS does in fact "ignore" information it receives from the lateral line system with respect to water temperature (Dijkgraaf, 1940; Sullivan, 1954). If the CNS does successfully ignore near-field effects

of the sort produced in these experiments, then there would have to be significant differences in the temporal pattern of the afferent discharges between those produced by near-field water displacements and those produced by conventional water current displacements.

Perhaps the most interesting aspect of the results is showing that exposure of brook trout to sublethal doses of DDT greatly potentiates the response of the lateral line to mechanical disturbance and that this effect of DDT is more pronounced at lower temperatures. DDT-induced instability in sensory nerves is well documented for animals other than fish, particularly insects. However, the fact that this effect on the lateral line nerve of trout is greater at lower than at higher temperatures is not common. In insects the DDT effect on sensory nerves has a positive temperature coefficient, although for the CNS of the cockroach the temperature coefficient for DDT action is negative (Eaton and Sternburg, 1964). In fact Eaton and Sternburg used their findings to suggest an explanation for the negative temperature coefficient for DDT toxicity in insects: although the initial and presumably primary attack of DDT may be upon sensory nerves, it is events occurring within the CNS which are responsible for the overall negative temperature coefficient of DDT toxicity. For fish, although the question seems not to have been asked frequently, the evidence indicates that here too DDT is more toxic (in terms of lethality) at lower than at higher temperatures (Cope, 1965; Thompson, 1964). It would be interesting to investigate the relation between temperature and DDT effects on CNS activity for fish.

There remains one final aspect of the results which deserves mention. Work in this laboratory (Ogilvie and Anderson, 1965; Javaid, MS, 1967) has shown that fish treated with sublethal doses of DDT exhibit a violent avoidance reaction ("cold response") when they encounter, when swimming in a horizontal temperature gradient, water of about 5 C or colder. This response is totally absent in untreated fish. From the rapidity with which this "cold response" occurs, it seems likely that it is initiated by sensory nerves. We have cut the trunk lateral lines of DDT-treated fish but the "cold response" persists unabated. This does not, of course, entirely exclude the lateral line system from participating in the response since we made no attempt to make inoperative that part of the lateral line system located in the head region. It is possible, however, that the effect of DDT on the lateral line as seen in these experiments is typical of the effect on sense cells in general. If that were the case, then the "cold response" might be accounted for by the abrupt increase in the sensitivity of the normal receptors to water of about 5 C or colder.

ACKNOWLEDGMENTS

This work was supported by grants-in-aid from the Fisheries Research Board of Canada and the National Research Council of Canada. I am particularly grateful to Dr G. J. Thiessen and Dr E. A. Shaw of the Acoustics Section of the Division of Applied Physics of NRC for their assistance in determining the acoustical properties of the stimulus used in these experiments.

REFERENCES

COPE, O. B. 1965. Agricultural chemicals and fresh-water ecological systems. *In* C. O. Chichester [ed.] Research in pesticides. Proceedings of the conference on research needs and approaches to the use of agricultural chemicals from a public health viewpoint. Univ. Calif., Davis, Calif., Oct. 1–3, 1964. Academic Press, Inc., New York. p. 115–127.

DIJKGRAAF, S. 1940. Untersuchungen über den Temperatursinn der Fische. Z. Vergleich. Physiol., **27**: 587–605.

EATON, J. L., AND J. STERNBURG. 1964. Temperature and the action of DDT on the nervous system of *Periplanata americana* (L.). J. Insect Physiol., **10**: 471–485.

JAVAID, M. Y. MS, 1967. Some factors affecting the temperature selection of three species of salmonids. Ph.D. Thesis. Dept. Biol., Carleton University, Ottawa, Ont.

KATSUKI, Y., AND S. YOSHINO. 1952. Response of the single lateral-line nerve fiber to the linearly rising current stimulating the endorgan. Japan. J. Physiol., **2**: 219–231.

KEENLEYSIDE, M. H. A. 1955. Some aspects of the schooling behaviour. Behaviour, **8**: 183–248.

OGILVIE, D. M., AND J. M. ANDERSON. 1965. Effect of DDT on temperature selection by young Atlantic salmon, *Salmo salar*. J. Fish. Res. Bd. Canada, **22**(2): 503–512.

SULLIVAN, C. M. 1954. Temperature reception and responses in fish. Ibid., **11**(2): 153–170.

THOMPSON, P. E. 1964. Progress in sport fishery research, 1963. U.S. Fish Wildlife Serv., Circ. No. 178. 180 p.

An Artificial Reef for Lobsters (*Homarus americanus*)[1]

By D. J. Scarratt

Fisheries Research Board of Canada
Biological Station, St. Andrews, N.B.

ABSTRACT

In July 1965 a rock reef covering 2740 m² was built in 17 m of water in Northumberland Strait, eastern Canada. Systematic observations by scuba divers showed the development of a fauna and flora including a number of lobsters. The lobster biomass after 2 years was less than that on productive lobster grounds nearby, although the average size of lobsters was larger. There was no evidence of larval settlement, colonization being by immigration.

RÉSUMÉ

En juillet 1965 un récif rocheux, couvrant un étendu de 2,740 m², fut construit dans 17 m d'eau au détroit de Northumberland à l'est du Canada. Des observations systématiques, faites par des scaphandriers, ont démontré le développement floral et de la faune y compris un nombre de homard. La masse de homard était moindre que dans leur habitat naturel bien que leur taille soit plus grosse que la moyenne. Il n'y a pas d'évidence de colonie de larves sur le récif. La colonisation s'est faite par immigration.

INTRODUCTION

There are several accounts of the biological changes after modification of underwater substrates (Stroud, 1961, 1966; Carlisle et al., 1964; Unger, 1966) which describe the improvement in the carrying capacity of the area for sportfish. This paper describes attempts to create a habitat for the American lobster, *Homarus americanus*, which is in high commercial demand.

Lobsters are most abundant in rocky areas where they may create and occupy holes or burrows (Fig. 1). To test whether the scarcity of suitable cover might limit lobster populations in areas where other conditions were suitable, groups of terracotta drainage tiles were laid in selected areas of sea bed in the summer of 1962. Several were occupied by lobsters (Fig. 2). However, the drainage tiles were occupied by lobsters of more or less uniform size. The present experiment was designed to accommodate a wider size range by duplicating the structure of existing lobster grounds with a man-made rocky reef.

METHODS

On the basis of a geological survey of Kouchibouguac Bay (Fig. 3) in 1964 (Kranck, 1967), a locality was selected where the sea bed is of a poorly sorted glacial till and not undergoing hydrodynamic sorting at present. Thus,

[1]Received for publication June 24, 1968.

J. Fish. Res. Bd. Canada, 25(12): 2683–2690, 1968.
Printed in Canada.

there was little likelihood of the reef becoming covered over or dispersed. The high gravel content suggested that the substrate was strong enough to carry the reef.

In the spring of 1965 the proposed locality was explored by Fisheries Research Board divers who selected a site in 17 m of water at low tide. The sea bed consisted of hard sand in the east and coarse gravelly sand in the west. No lobsters were seen on the site but there were known concentrations 2.5 km away at most. Accordingly lobsters were available to populate the reef naturally and any increase in numbers would be apparent. Sandstone from Richibucto Cape was towed to the reef site in steel, twin-compartment dumping scows. Individual rocks ranged from 5 to 100 cm in diameter and up to 15 cm thick. This provided for a wide range of burrow sizes and allowed divers to thoroughly examine any part of the reef, few rocks being too big to move under water.

The optimum load of rock was 30 m^3 per compartment which gave a reasonable spread of suitable thickness. Dumping began on June 30 and was concluded on July 9. About 1500 m^3 of rock were delivered and on completion the reef was mapped (Fig. 4). The total area, excluding areas missed by the rock fill, was 2740 m^2 (0.68 acre). The long E–W axis was at right angles to the tidal currents.

The reef has been examined regularly from May to October each year. (This report includes observations up to and including October 1967.) A superficial examination is made by divers working in pairs. They swim slowly around the reef just inside the perimeter and about 1 m above the bottom. The outside diver swims so that the edge of the reef is clearly visible and the inside diver keeps the other just at his limit of vision. In this way they cover a strip up to about 9 m wide, depending on the underwater visibility. To examine the centre the divers orient themselves by known landmarks. There is a "gully" which in effect cuts the reef into two portions and one half of the reef can be examined in 30–45 min.

For detailed examinations, the divers swim much closer to the bottom, checking each boulder or burrow for lobsters. Initially, large areas could be covered in detail but as the lobster population increased, this was not possible. In 1967 two areas, A and B, bordering the periphery were measured accurately and marked off from the rest of the reef by lines laid along the bottom. Each survey usually comprises a superficial examination together with a detailed examination of part of the reef.

With the exception of a few samples taken of the developing fauna and flora, no material, living or otherwise, has been removed from the reef and all rocks moved have been carefully replaced. The net result has been to interfere as little as possible with the natural development of the reef. Lobsters removed from burrows have been sexed and measured and in some cases tagged under water with either a modified sphyrion tag (Scarratt and Elson, 1965) or a metal-elastic carapace tag (Wilder, 1954). Each lobster examined has been returned to its burrow. Unfortunately it is not known to what extent handling

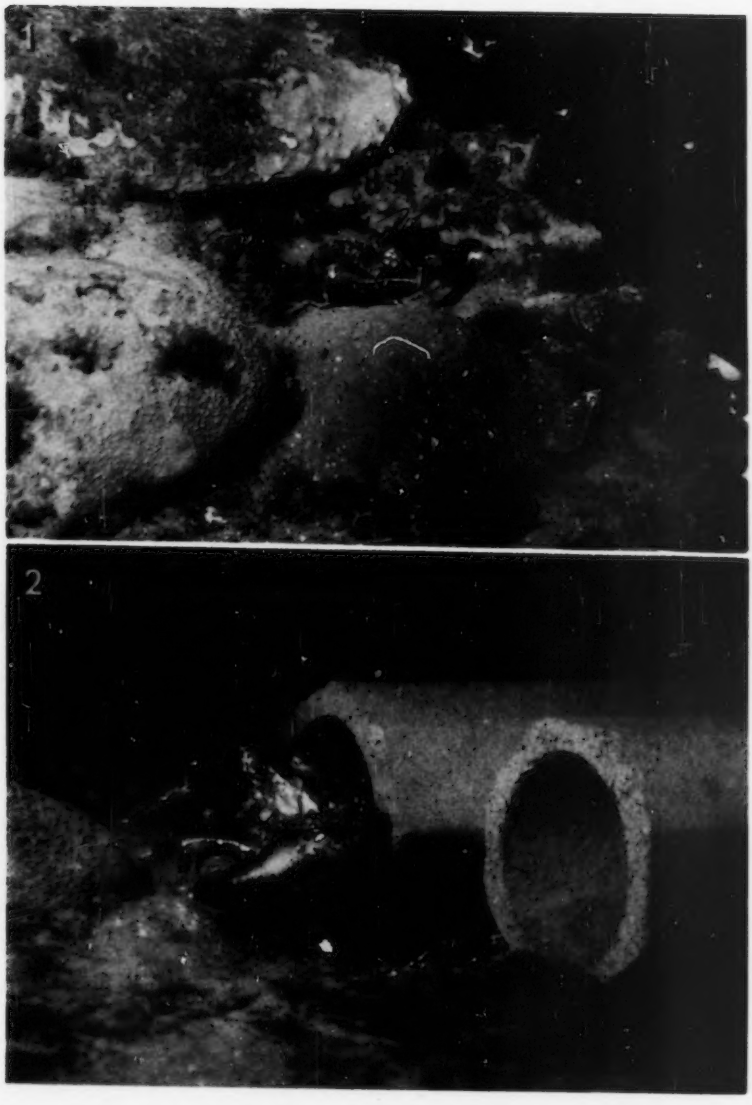


FIG. 1. Lobster in natural habitat at 11-m depth, Richibucto, N.B., August 1966.

FIG. 2. Lobsters associated with terracotta drainage tiles at 11-m depth, Richibucto, N.B., August 1962. The claws of the second lobster are visible between the two tiles.

Scarratt — J. Fish. Res. Bd. Canada

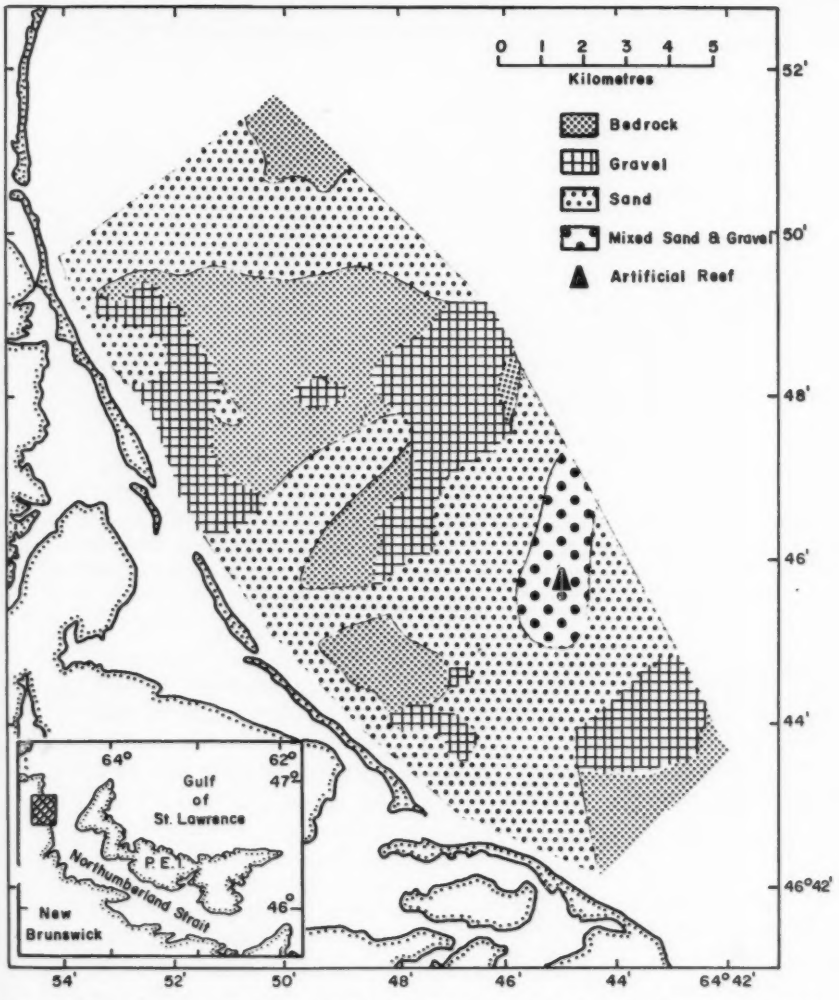


FIG. 3. Kouchibouguac Bay showing bottom lithology (after Kranck, 1967) and reef site. Inset: Northumberland Strait showing location of Kouchibouguac Bay.

lobsters affects their subsequent behaviour. There has been some commercial lobster fishing in the vicinity of the reef, but it is considered that this has had little or no effect upon the reef population.

Lobster populations on a rocky area inshore from the reef have also been systematically surveyed. Divers collect by hand and subsequently weigh and measure all lobsters from a square area temporarily enclosed by a nylon net fastened to a folding metal frame. This net is set four times, giving a total of

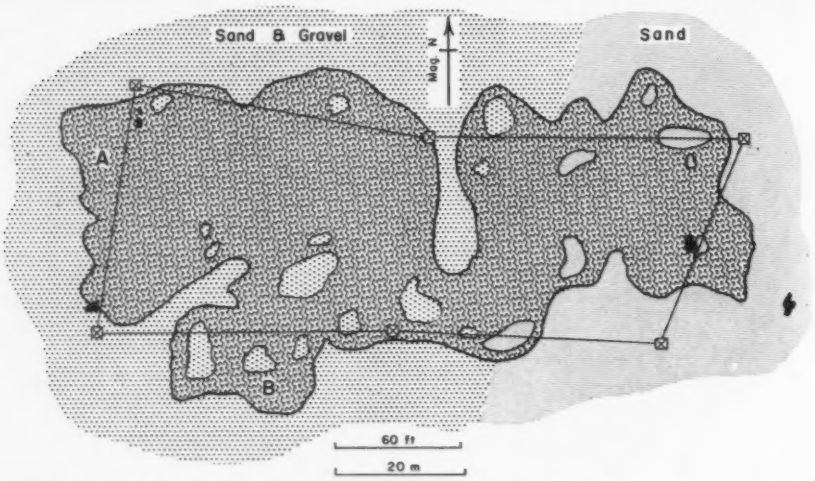


FIG. 4. Map of artificial reef. Prominent rocks are shown black; areas not covered by rock are shown with appropriate sand or gravel background. Measured area A is delimited by a rope laid between concrete blocks in the NW and SW corners. Area B is similarly delimited by a rope laid from the SW corner to the south centre block. Ropes around the remainder of the reef serve as a guide to divers.

83.6 m² (100 yard²) examined at each station. The three deepest stations yielding the largest number of lobsters were considered to represent highly productive lobster territory in a depth comparable with that of the reef. The three stations are deeper than 15 m and each yielded 10 or more lobsters per sampling (Table III).

OBSERVATIONS

1965

The pre-reef epifauna consisted of numerous sand dollars (*Echinarachnius parma*) on the sand (Fig. 5), and occasional scallops (*Placopecten magellanicus*) on the gravel. There,were a few fish, notably sculpins (*Myoxocephalus* sp.)

By the end of August, 7 weeks after the reef was completed, there were a few starfish (*Asterias vulgaris*) and sea urchins (*Strongylocentrotus droebachiensis*) browsing on a very short turf of algae, bryozoans, and hydroids. Thirteen lobsters (Fig. 6) were seen and examined. By October, the hydroid growth was 10–15 mm long and a few cunners (*Tautogolabrus adspersus*) were observed. Several sculpins, eelpouts (*Macrozoarces americanus*), crabs (*Cancer irroratus*), and one sea raven (*Hemitripterus americanus*) were recorded.

A total of 21 lobsters (Table I) were captured and measured on the reef before diving ceased. Seventeen of these lobsters were tagged. Only one of the 17 was subsequently seen that fall.

TABLE I. Numbers and average carapace lengths of lobsters sampled at reef, 1965–67. (Legal lobsters have a carapace length equal to or greater than 63.5 mm.)

Date	No. of lobsters			Mean carapace length (*mm*)
	Total	Legal	Tagged	
Summer and fall 1965	21	10	17	61.1± 8.0*
Aug. 1966	29	9	–	61.7± 5.1
Sept. 1966	12	4	12	63.9±10.6
Oct. 1966	34	12	34	63.4±17.8
July 1967	15	2	–	52.4± 9.4
Aug. 1967	19	3	–	56.7± 7.0
Sept. 1967	10	1	–	53.1± 8.2

*Standard deviation of sample.

1966

By May 1966, the fauna was better developed than it had been the previous October and some hydroids were up to 6–8 cm tall (Fig. 7). There were also some sponges, bryozoans, and tunicates visible on the rocks. The motile fauna was similar to that observed the previous fall. One small cod (*Gadus morhua*) was seen. The rocks were covered with a light, flocculent detritus. Only one lobster was seen.

In June it was noted that the bryozoans and hydroids were located mainly on the sides of the boulders rather than on the top, where there was a layer of silt. Four lobsters were seen, one of which carried a tag inserted the previous September.

During a superficial examination made on August 22, 26 lobsters were counted and it was concluded that there had been an influx. The next day an attempt was made to count the total stock. The periphery and most of the central area of the reef were examined carefully and 51 lobsters counted. They appeared to be more abundant near the edge of the reef. The total was estimated to be about 60 animals. Later (August 25) the population was sampled to find the size distribution. Twenty-nine animals (Table I) were sexed and measured off about one half of the reef area. In September, a sample of 12 was measured and tagged. In October, 34 animals from slightly more than one half the reef were measured and tagged.

1967

During the early part of the 1967 season the water was particularly cold and turbid and the first examination could not be made until July 12, when on the first dive 12 lobsters were seen. Area A of the reef was sampled and 15 lobsters measured, including one that had been tagged and released the previous fall. A superficial examination of the rest of the reef revealed a further 23 lobsters. All the lobsters were in burrows and sluggish due to the low temperature (2.4 C). Many were not visible until the burrow roof had been removed.

This suggests strongly that a number had overwintered on the reef.

The sessile fauna had developed considerably; hydroid colonies had largely been replaced by colonies of erect and spreading polyzoans located on the upper faces of the rocks and there were many tunicates and sponges, particularly on the vertical or overhanging rock faces (Fig. 8). Common starfish (*Asterias vulgaris*) were more numerous and one or two *Henricia sanguinolenta* were seen. Sculpins were more numerous than before and there were many more eelpouts, including juveniles occupying burrows under rocks.

In late August, 8 and 11 lobsters were found in areas A and B respectively, and in September, 10 in area A. No count was made of the total population. During the August 10–October 10 lobster fishing season, 9 of the 46 lobsters tagged on the reef in 1966 were captured by fishermen. The place of recapture is not known for two of these. The other seven had moved straight-line distances of 5–20 km and were all taken inshore in ca. 4 m of water.

DISCUSSION

At the conclusion of diving operations in 1965, it was considered that although the reef fauna was beginning to develop, there was an inadequate food supply for the lobsters finding the reef. Of the 17 lobsters tagged, only one had been subsequently seen on the reef that fall, and the lobsters were thought to be essentially transitory.

The sighting of only one lobster in May of 1966 implies that the 1965–66 overwintering population was small, whereas the relatively high number at the beginning of the 1967 season suggests that a larger number passed the 1966–67 winter on the reef.

The single tag sighting on the reef in 1967 and the returns from inshore suggest that the lobsters were highly mobile throughout the fall of 1966. Even after diving operations cease in October, the water is relatively warm and lobsters are probably active until early December or thereabouts. Mean surface temperatures for the years 1951–67 at Borden, P.E.I., for November are 6.5 C and for December, 1.1 C (L. M. Lauzier, personal communication). McLeese and Wilder (1958) showed that catchability of Passamaquoddy Bay lobsters approaches zero between 2 and 3 C. Personal observations of lobsters in water less than 3 C showed them to be burrowed under rocks and essentially quiescent.

Estimates of the biomass of lobsters on the reef or portions of it in 1966 and 1967 ranged from 4.3 to 13.1 g/m² wet weight (Table II). The mean value in 1967 was 9.6 g/m², which is possibly a high estimate for the whole reef since the sampling areas were near the periphery. This is less than the average biomass at the three deep inshore stations, 12.6 g/m² (Table III). Assuming that the reef, when developed, will be as productive as these three stations, the total potential weight of lobsters could be in the order of 34 kg. Assuming that the measured area A sampled in 1967 (Table II) is representative of the whole reef, then the total number of lobsters at that time might have been

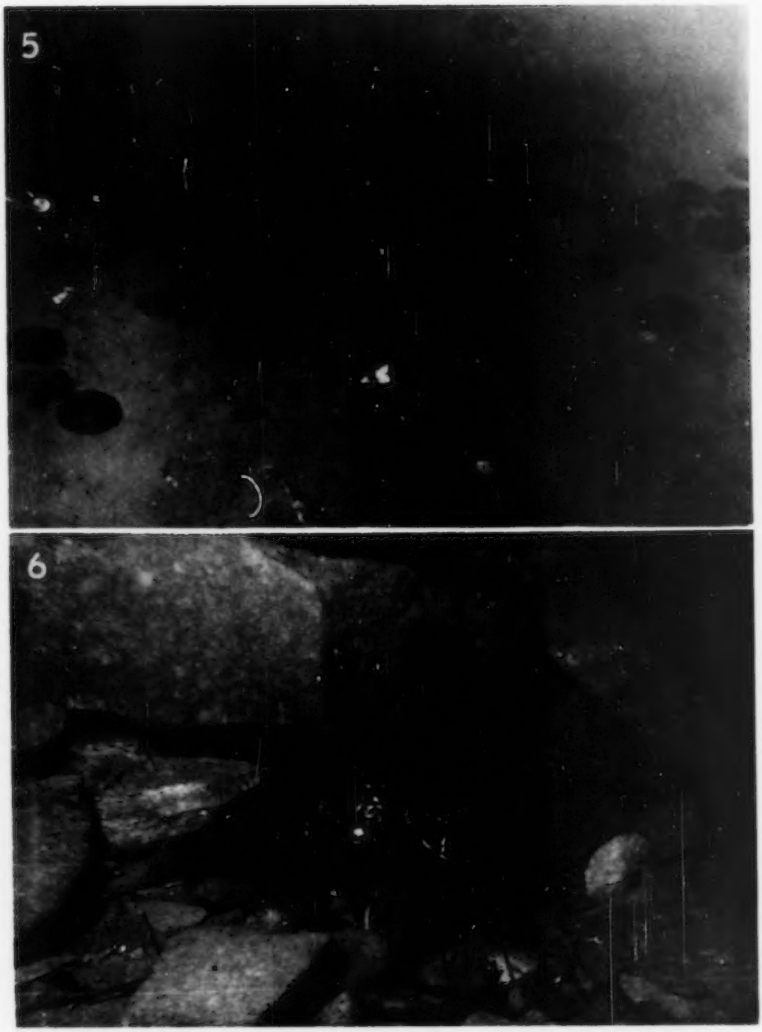


FIG. 5. Reef site, east end, before deposition of rock.

FIG. 6. Lobster occupying crevice on artificial reef, September 1965.

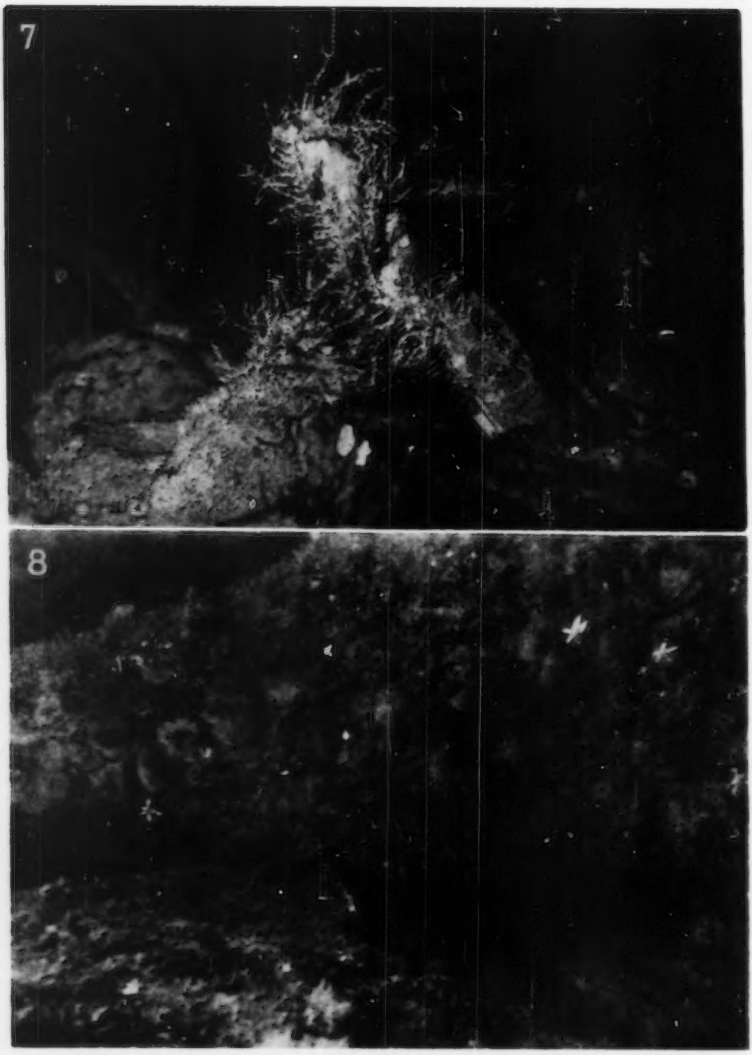


FIG. 7. Artificial reef epifauna, May 1966. Several unidentified hydroids and bryozoans are clearly visible.

FIG. 8. Artificial reef, July 1967. Fauna on a vertical rock face includes bryozoans, tunicates, sponges, and starfish.

TABLE II. Biomass of lobsters on artificial reef 1966–67. Weights are from unpublished length–weight data obtained from Kouchibouguac Bay lobsters.

Date	Area examined (m^2)	No. of animals	Total wt (g)	Estimated biomass (g/m^2)
Aug. 1966	2,740	ca. 60	11,700[a]	4.3
July 1967	145[b]	15	1,900	13.1
Aug. 1967	145	8	1,130	7.8
	200[c]	11	1,675	8.4
Sept. 1967	145	10	1,300	9.0

[a]Average estimated weight of 29 lobsters measured on the reef August 1966 was 195 g.
[b]Area A.
[c]Area B.

TABLE III. Numbers, average carapace lengths, total weights, and biomass of lobsters on three sample areas on established lobster grounds in 1966 and 1967. Area examined in each season was 250.8 m^2.

Date	No. of lobsters		Mean carapace length (*mm*)	Total wt (g)	Estimated biomass (g/m^2)
	Total	Legal			
Spring 1966	46	0	41.6±11.3[a]	3202	12.8
Fall 1966	41	1	40.9±11.3	2645	10.6
Spring 1967	47	1	42.3±12.2	3576	14.3
				Mean	12.6

[a]Standard deviation of sample.

between 150 and 280 and the total biomass between 21 and 36 kg, the higher estimates being for the early part of the season before the lobsters became very mobile.

The average size of lobsters on the artificial reef (Table I) is larger than that on the inshore areas (Table III). The proportion of legal-size lobsters (above 63.5 mm carapace length) on the reef is also higher, although this has declined from 48% in 1965 to 33% in 1966 to 14% in 1967.

Personal observations in Kouchibouguac Bay, where lobsters are small and very abundant, suggested a relationship between the sizes of lobsters in an area and the sizes of the rocks or boulders. Insofar as large burrows are scarce in small-boulder areas, large lobsters are scarce also. It may be that lobsters move off the small-boulder areas as they approach legal size.

Dybern et al. (1967), studying European lobsters (*H. vulgaris*) in Sweden, found that smaller lobsters are more prone to hide in burrows than larger

lobsters, although they also consider that although lobsters are vagabonds, moving from one burrow to another, they do not cover a great area. An explanation for the decreasing average size of lobsters at the reef could be that the reef was initially discovered by larger lobsters which were displaced from the inshore habitat by outgrowing their burrows, and were joined later by smaller, less vagrant animals. The very low proportion of larger lobsters in 1967 may in part be due to delayed moulting resulting from unusually cold water in the spring and summer of 1967 (personal observations).

The reef was designed to offer burrows for lobsters of all sizes and to date lobsters ranging from 41 to 153 mm carapace length have been recorded on it. No lobsters small enough to be considered newly settled have been seen. Since a 41-mm carapace length lobster is probably not less than $3\frac{1}{2}$ years old (Wilder, 1953), it must be concluded that the reef has been colonized by immigration.

ACKNOWLEDGMENTS

I am indebted to Dr B. R. Pelletier and Miss Kate Kranck of the Marine Geology Division, Department of Energy, Mines, and Resources, Bedford Institute, Dartmouth, N.S., who surveyed the area. The reef was constructed by Mr Leo LeBlanc of Richibucto, N.B., under the supervision of the Department of Public Works. I was ably assisted under water by Messrs I. S. Rote, R. Lowe, A. F. Kenney, P. W. G. McMullon, D. E. Graham, G. E. Raine, and A. J. Wilson; we are most appreciative of the assistance of Capt P. T. Ossinger and the crew of M.B. *Pandalus II* for their contribution to our welfare and safety while diving. Finally I would like to thank Dr D. G. Wilder for his assistance at all stages of this project.

REFERENCES

CARLISLE J. G., JR., C. H. TURNER, AND E. E. EBERT. 1964. Artificial habitat in the marine environment. Calif. Fish Game Fish Bull. No. 124. 93 p.

DYBERN, BERNT I., LEIF JACOBSSON, AND HANS HALLBÄCK. 1967. On the habitat behaviour of the lobster (*Homarus vulgaris*) in Swedish waters. Medd. Havsfiskelab., Lysekil, No. 36. 13 p.

KRANCK, 1967. Bedrock and sediments of Kouchibouguac Bay, New Brunswick. J. Fish. Res. Bd. Canada, **24**(11): 2241–2265.

MCLEESE, D. W., AND D. G. WILDER. 1958. The activity and catchability of the lobster (*Homarus americanus*) in relation to temperature. Ibid., **15**(6): 1345–1354.

SCARRATT, D. J., AND P. F. ELSON. 1965. Preliminary trials of a tag for salmon and lobsters. Ibid., **22**(2): 421–423.

STROUD, R. H. 1961. Artificial saltwater fishing reefs. Sport Fish. Inst. Bull. No. 121. p. 1–3.

1966. Artificial reefs as tools of sport fishery management in coastal marine waters. Ibid., No. 170. 8 p.

UNGER, IRIS. 1966. Artificial reefs — a review. Am. Litt. Soc., Spec. Publ. No. 4. 74 p.

WILDER, D. G. 1953. The growth rate of the American lobster (*Homarus americanus*). J. Fish. Res. Bd. Canada, **10**(7): 371–411.

1954. The lobster fishery of the southern Gulf of St. Lawrence. Fish. Res. Bd. Canada, Atlantic Biol. Sta. Circ., Gen. Ser., No. 24. 16 p.

NOTES

Metabolism of the Radioisotope ^{65}Zn in the Freshwater Mussel *Anodonta californiensis*

One of the principal gamma emitters of biological significance identified in Hanford's reactor effluent discharged to the Columbia River is ^{65}Zn (Watson et al., 1963). Certain marine mollusks, such as oysters (*Crassostrea gigas* and *Crassostrea virginica*), the bay mussel (*Mytilus edulis*), and the razor clam (*Siliqua patula*), accumulate ^{65}Zn from sea water and hence serve as biological indicators of this isotope in the marine environment (Chipman et al., 1958; Watson et al., 1961, 1963). No comparable analyses exist for this isotope in freshwater lamellibranchs. For this reason, we have studied the metabolism of this radioisotope in the freshwater mussel *Anodonta californiensis*.

Mussels were collected from several ponds adjacent to the Columbia River, downstream from all reactor sites in the Hanford Reservation. The first experiment, designed to determine the effect of ^{65}Zn concentration, employed three mussels in each of three plastic pans. Each pan contained 4 liters of aerated river water maintained at river temperature (40.8–44.8 F). The mussels were exposed for 5 days to ^{65}Zn concentrations at initial levels of 1, 10, or 100 μCi/liter. The water was replaced on the 3rd day of the experiment with water of the initial ^{65}Zn concentration. On the 5th day the animals were killed for whole body counting. The accumulation of ^{65}Zn was proportional to the concentration of isotope in the water to which the mussels were exposed.

A second experiment was set up to determine the tissue distribution of ^{65}Zn. Four mussels (length 105–110 mm) were placed in each of six trays. The trays contained 8 liters of river water, which was changed twice weekly, continuously aerated, maintained at river temperature, and kept at a concentration of 100 μCi/liter of ^{65}Zn by daily additions of the isotope. The four mussels in a tray were killed after exposures of 1, 2, 4, 8, 16, or 36 days. Three mussels were analyzed for ^{65}Zn by gamma counting in the mantle and palps, the gills, the adductor muscles, the foot, the gonad and visceral mass, and the shell. Stable zinc analyses were also made on these tissues from six mussels by means of an atomic absorption spectrophotometer. One mussel from each group was fixed in methanol for autoradiographic examination. Tissue sections were dipped in 2:1 ratio mixture of K-5 emulsion and water, and exposed for 20 hr for autoradiographic study.

The mussels showed a continuing increase in ^{65}Zn concentration throughout the 36-day experiment, with final body burdens of approximately 100 μCi in the soft tissues and 300 μCi on the shell. The concentrations of ^{65}Zn in various tissues, as a function of time, are shown in Fig. 1. Total tissue burdens are shown in Fig. 2. After 36 days of exposure, 75% of the ^{65}Zn was

J. Fish. Res. Bd. Canada, 25(12): 2691–2694, 1968.
Printed in Canada.

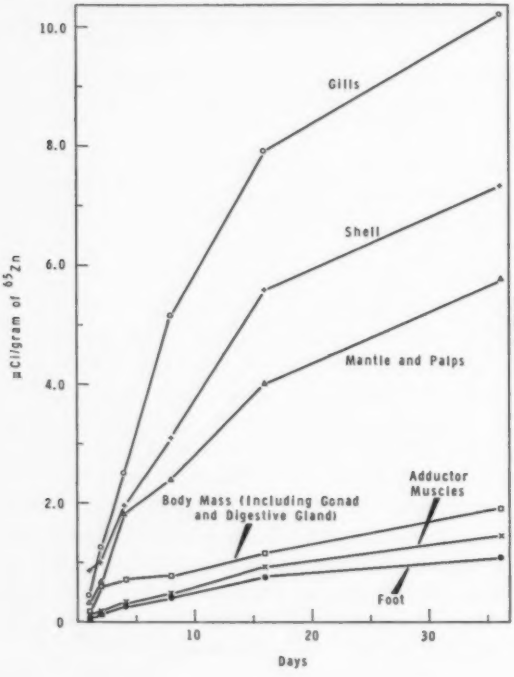


FIG. 1. Uptake of ^{65}Zn (μCi/g) by various parts of the freshwater mussel *Anodonta californiensis* (100 μCi/liter of water).

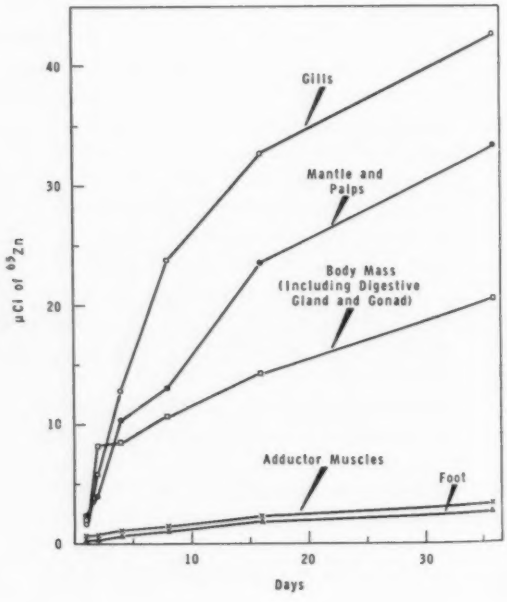


FIG. 2. Total tissue burden of ^{65}Zn in the soft parts of the freshwater mussel *Anodonta californiensis* (100 μCi/liter of water).

in the gills, mantle, and palps. The stable zinc content of six mussels showed a similar pattern of distribution, as is evident in the following table:

Tissue	Zinc content (*mg per g of wet tissue*)	Range among samples
Gill	0.42	0.29–0.57
Mantle and palps	0.08	0.038–0.14
Body mass (including gonad and digestive gland)	0.044	0.030–0.083
Adductor muscles	0.035	0.025–0.047
Foot	0.033	0.024–0. 040

Autoradiographs showed some ^{65}Zn in all tissues except Leydig cells and the mucous cells of the epithelial layers. The radioisotope was accumulated both intercellularly and intracellularly, but little was adsorbed on the surface of the animals.

The distribution of the ^{65}Zn isotope was as follows. The hemocytes contained large amounts (Fig. 3 and 4). Heavy concentrations were localized at the tip and base of the outer mantle epithelium (Fig. 3), whereas the inner mantle epithelium contained little. Moderate amounts were localized in the tips of the epithelial cells of the gills. A moderate concentration was present in the tips of the epithelial cells covering the foot, whereas the basophilic gland cells of this organ accumulated little. The gonadal ducts were heavily labelled throughout the cytoplasm of the epithelial cells. The smooth muscle throughout the body had moderate amounts, whereas the heart muscles were heavily labelled. The epithelium of the intestine, style sac, and rectum contained moderate amounts concentrated in a layer halfway between the nucleus and the tip of the cell (Fig. 4). The amorphous connective tissue beneath the intestinal tract contained little or none (Fig. 4). The secretory tubules of the digestive gland contained ^{65}Zn distributed throughout the cytoplasm. The visceral ganglion contained ^{65}Zn in both the nerve fibers and the nerve cells. Extremely heavy concentrations were observed in the epithelial cells of the kidney and in the lumen of the kidney near the surface of the epithelium.

The oyster *Crassostrea virginica* has been reported to show high concentrations of ^{65}Zn in the gills and low concentrations in the adductor muscle (Chipman et al., 1958). This is in agreement with our findings in the freshwater mussel *A. californiensis*. Stable zinc concentrations were found to be highest in the palps, gills, and mantle of the oyster (Chipman et al., 1958; Galtsoff, 1964), which is similar to our findings in *A. californiensis*. In the scallop *Pecten irradians*, the kidney was reported to contain approximately five times as much ^{65}Zn as any other tissue (Chipman et al., 1958), which agrees with our autoradiographic observations.

Zinc is accumulated by ingestion in the intestine and dispersed by the hemolymph throughout the body of the oyster (Galtsoff, 1964). The absorption of ^{65}Zn into the tissues of *A. californiensis* probably occurs through the epithelium of the mantle and the gills, and through the wall of the digestive tract.

The authors would like to thank Mr W. L. Templeton for his critical evaluation of the manuscript. Technical assistance from Mr J. D. Maulsby is gratefully acknowledged. Analysis of stable zinc was performed by Mr R. F. Keough. The freshwater mussles were kindly identified by Dr Henry van der Schalie, Professor of Zoology, University of Michigan Museum of Zoology. This paper is based on work performed under U.S. Atomic Energy Commission Contract AT(45-1)-1830.

Departments of Biology and Ecosystems
Battelle Memorial Institute
Pacific Northwest Laboratory, Richland, Washington

GILBERT B. PAULEY[1]
ROY E. NAKATANI

Received for publication August 13, 1968.

REFERENCES

CHIPMAN, W. A., T. R. RICE, AND T. J. PRICE. 1958. Uptake and accumulation of radioactive zinc by marine plankton, fish, and shellfish. U.S. Fish Wildlife Serv., Fish. Bull., **58**(135): 279–292.

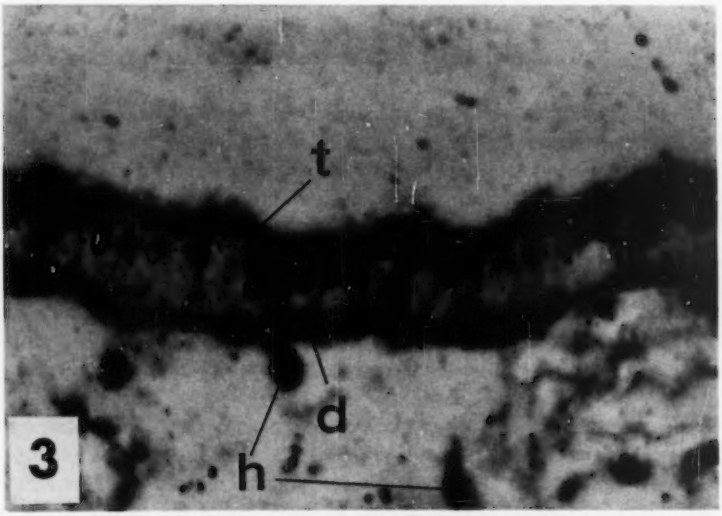
GALTSOFF, P. S. 1964. The American oyster, *Crassostrea virginica* Gmelin. Ibid., **64**: 1–480.

WATSON, D. G., J. J. DAVIS, AND W. C. HANSON. 1961. Zinc-65 in marine organisms along the Oregon and Washington coasts. Science, **133**: 1826–1828.

WATSON, D. G., J. J. DAVIS, AND W. C. HANSON. 1963. Interspecies differences in accumulation of gamma emitters by marine organisms near the Columbia River mouth. Limnol. Oceanog., **8**(2): 305–309.

(FIG. 3 and 4 *opposite*)

[1]Present address: Department of Organismic Biology, University of California, Irvine, Calif. 92664.



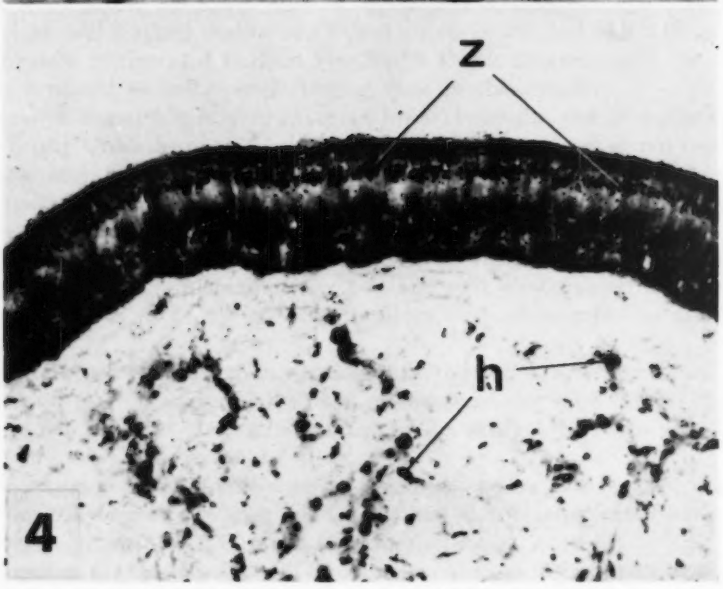


FIG. 3. Autoradiograph of the outer mantle epithelium of a freshwater mussel, showing localization of ^{65}Zn at the bases (*d*) and the tips (*t*) of the cells. Note isotope in hemocytes (*h*). 400×. (Small black dots indicate the location of the radioisotope.)

FIG. 4. Epithelium of freshwater mussel intestine, showing localization of ^{65}Zn (Z) between the nuclei and cell tips. Note ^{65}Zn is present in the hemocytes (*h*) in the lighter connective tissue. 155×. (Small black dots indicate the location of the radioisotope.)

Effects of Chilled Storage on Viability of Stored Ova and Sperm of Sockeye and Pink Salmon

Earlier tests on sockeye (*Oncorhynchus nerka*) and pink (*O. gorbuscha*) salmon indicated that ova and milt without added water may be held at temperatures of 8–9 C for at least 8–12 hr without loss of fertility, and that pink salmon milt appeared capable of retaining its initial fertility up to 33 hr under these conditions (Withler and Humphreys, 1967). Comparison of those results with the work of others who had held salmon sex products at somewhat lower temperatures suggested that cooler storage might prolong the fertile period. To examine this possibility, the fertility of ova and milt of sockeye and pink salmon, without added water, held both at ambient stream temperatures and under refrigeration, was examined during the fall of 1967 at Lakelse Lake, British Columbia.

Preparation of spawn for storage. — Collection of spawners, spawn-taking, and preparation of samples for storage were identical to the procedures employed in 1966 (Withler and Humphreys, 1967), except that the samples of ova were placed in 32-oz (946-ml) glass jars instead of 1-gal (3.8-liter) plastic jars, and further, that one-half the samples of ova and milt were placed in a covered, refrigerated bath at the Scully Creek hatchery and the other half were placed as before in a floating rack in the stream.

Sockeye ova and milt were collected from 21 females and 17 males taken at the Scully Creek fence and held in pens. Paired samples of stored ova and milt from both the stream rack and the bath were treated with milt and ova from fresh, live fish at intervals increasing from 8 to 72 hr. The final pairs of samples were treated 333 hr after the first (0-time) pairs.

Pink salmon spawn was collected from 21 females and 8 males from the Lakelse River. Stored samples of ova and milt were treated at intervals increasing from 8 to 44 hr; the final samples were treated 188 hr after the first pair.

Temperatures. — During the period that the sockeye sex products were stored in the floating rack, mean stream temperature was 9.9 C (SD 0.7 degrees C, range 8.0–11.1 C). Mean temperature in the refrigerated bath was 2.9 C (SD 0.5 degrees C, range 1.7–3.7 C).

Pink salmon ova and milt were held in stream water of mean temperature 8.5 C (SD 0.4 degrees C, range 7.8–9.2 C), and in the refrigerated bath at a mean temperature of 3.2 C (SD 0.3 degrees C, range 2.6–3.7 C).

Detection of fertilization. — The samples of eggs were examined after 300 degree C-days of incubation, at which time live fertilized eggs were well "eyed" (eye pigment in the embryo clearly visible). The eggs were shocked with a fine jet of water to cause coagulation of the yolk material of unfertilized and dead eggs. Eggs in which coagulation occurred were placed in Stockard's[1]

[1]5 parts formalin, 4 parts glacial acetic acid, 6 parts glycerin, 85 parts water.

J. FISH. RES. BD. CANADA, 25(12): 2695–2699, 1968.
Printed in Canada.

solution to clear the yolk material; examination of these eggs under bright light and low magnification revealed those in which embryo development had taken place. Thus, fertilized eggs were considered to be those which were alive and contained developing embryos and those which had died but in which some embryo development had occurred prior to death.

Results for sockeye. — In five out of six trials of ova which had been stored up to 22 hr at temperatures about 9.9 C, fertilization was greater than 90% when fresh milt was applied (Fig. 1A). From 22 to 94 hr the proportion of

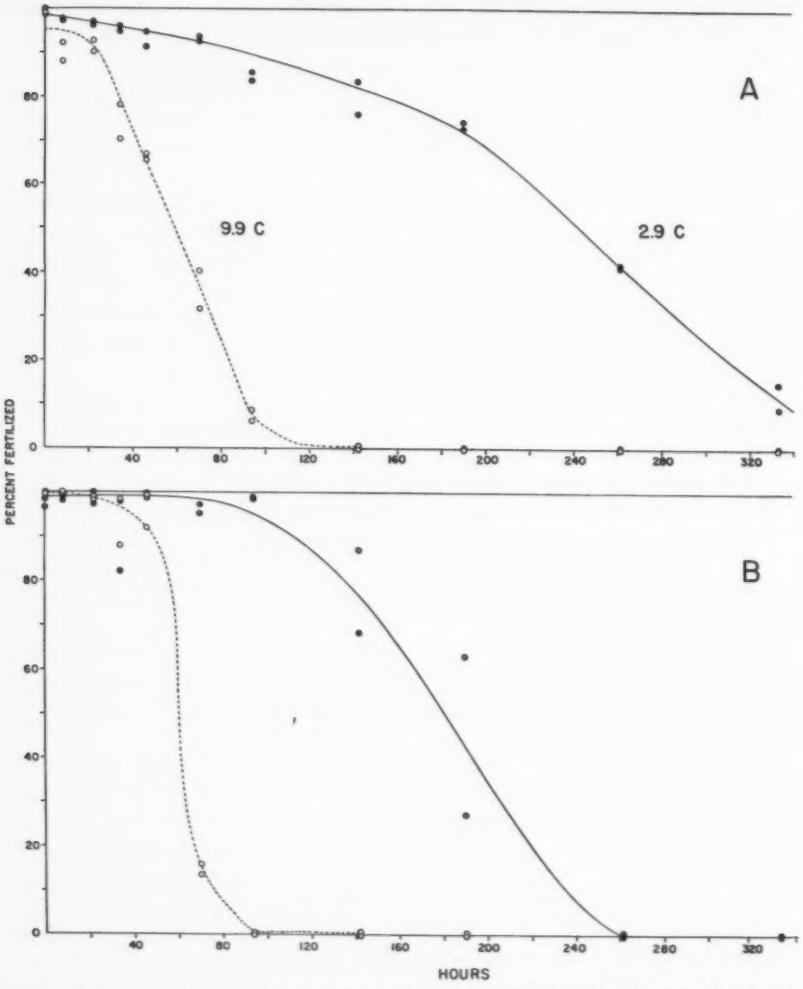


FIG. 1. Percentages, for sockeye salmon, of (A) ova fertilized by fresh milt after they had been stored for various times at two temperatures, and (B) fresh ova fertilized by milt that had been stored for various times at two temperatures. Each plotted point represents one test. The curves were drawn by eye.

stored ova fertilized by fresh milt declined to about 7%. After 94 hr of storage, no ova became fertilized except a few (0.3%) in one trial at 142 hr.

Ova stored at about 2.9 C remained fertile much longer (Fig. 1A). All samples treated up to 70 hr proved more than 90% fertile. After 70 hr the proportion which were fertile declined slowly until at 333 hr (ca. 14 days) about 12% were fertilized. Trials were discontinued after 14 days.

In 9 out of 10 instances, sockeye milt stored up to 46 hr at about 9.9 C fertilized over 90% of the fresh ova to which it was applied (Fig. 1B). Samples stored 70 hr fertilized only about 15% of the fresh ova. Thereafter, in trials involving up to 190 hr of storage, none of the fresh ova became fertilized except for a few (0.3%) treated with a sample of milt stored 142 hr.

At storage temperatures of about 2.9 C, however, sockeye milt retained fertilizing ability much longer (Fig. 1B). In 13 out of 14 trials with milt stored up to 94 hr, well over 90% of the fresh ova became fertilized. Two samples tested at 142 hr and two at 190 hr produced variable but declining proportions of fertilized eggs. After 261 hr of cool storage, one milt sample produced no fertilized eggs, the other a few (0.2%).

Results for pinks. — Pink salmon ova stored at about 8.5 C appeared to decline in fertility after 8 hr of storage (Fig. 2A). By 144 hr of storage the proportion fertilized by fresh milt was about 1–2%. Trials were discontinued after 144 hr.

When stored at about 3.2 C, over 85% of the ova remained fertile (in 9 out of 10 tests) for up to 46 hr (Fig. 2A). For periods of storage beyond 46 hr and up to 188 hr, the proportions fertilized by fresh milt declined to about 1–2%. No trials were made after 188 hr.

Pink salmon milt stored at about 8.5 C fertilized over 90% of fresh ova for up to 46 hr in 7 out of 10 tests (Fig. 2B). Thereafter the proportion of fresh ova fertilized dropped rapidly to about 30% after 94 hr of storage and zero at 144 hr.

When stored at about 3.2 C, pink salmon milt fertilized over 90% of the fresh ova in 7 out of 10 trials made during the period up to 46 hr of storage. The decline in fertility progressed more slowly after 46 hr than at 8.5 C, and a small proportion (about 10%) of fresh ova were fertilized after 188 hr of storage. No further trials were made.

Changes during storage. — As the period of storage increased, sockeye ova and milt changed in appearance. Ova stored at both 9.9 and 2.9 C began to change in colour after 46 hr; they appeared to become pinker than fresh ova. At later stages the colour became more variable — many were either brighter or paler in colour than fresh ova. Those stored at 9.9 C gave off a putrid odour at 190 hr whereas those stored at 2.9 C gave off a slightly putrid odour only after 333 hr of storage. Sockeye milt stored at the higher temperature began to thicken after 22 hr; at 70 hr it began to form soft curds when mixed with water in the washing process; by 190 hr it gave off a putrid smell. Milt stored at the lower temperature did not begin to thicken and form curds in water until after 142 hr of storage; by 333 hr it gave off only a slightly putrid odour.

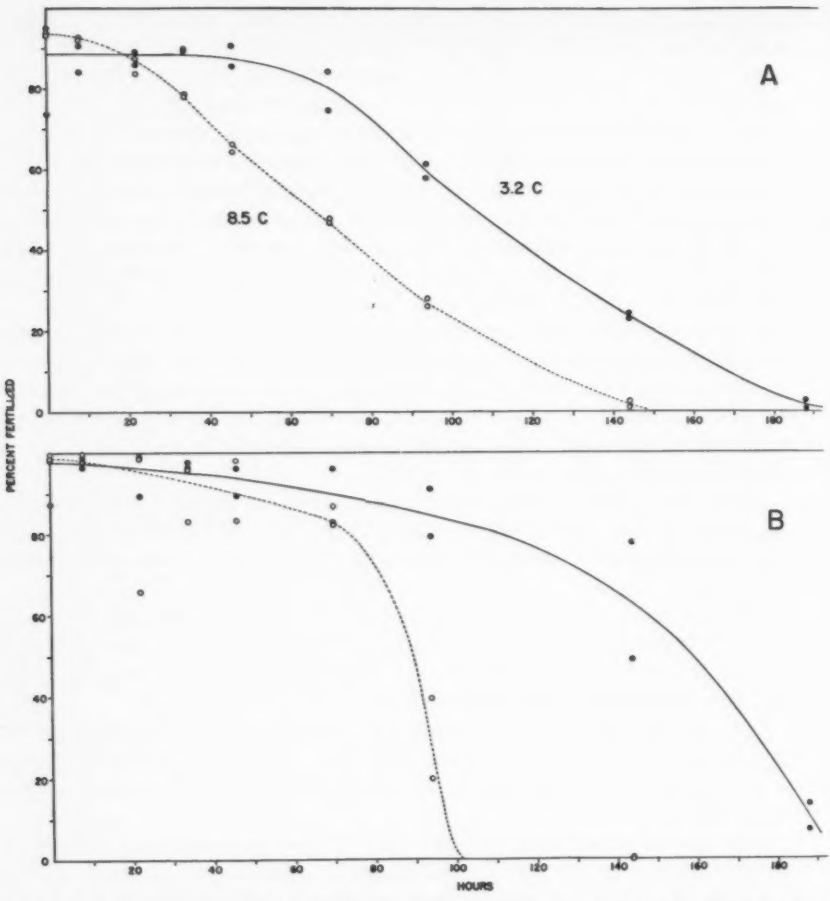


FIG. 2. Percentages, for pink salmon, of (A) ova fertilized by fresh milt after they had been stored for various times at two temperatures, and (B) fresh ova fertilized by milt that had been stored for various times at two temperatures. Each plotted point represents one test. The curves were drawn by eye.

Pink salmon ova stored at 8.5 C became more variable in colour than fresh ova at 70 hr; those stored at 3.2 C showed marked variation of colour after 94 hr. Dead ova (indicated by the opaque appearance associated with yolk coagulation) occurred in samples stored at both temperatures at 144 hr of storage or longer. Pink salmon milt stored at 8.5 C became viscous and formed soft curds when mixed with water after 34 hr, whereas that kept at 3.2 C became only slightly more viscous than fresh milt. At 46 hr, the chilled milt formed curds when mixed with water. The milt kept at higher temperatures gave off a putrid odour at 144 hr; that kept at lower temperatures did not become putrid before the end of testing (188 hr).

Discussion. — Comparison of the above findings with those on storage of salmon sex products in an earlier report (Withler and Humphreys, 1967) suggests that, under conditions otherwise similar to those of the earlier tests, lowering storage temperature to about 3 C provides a period of 2 to 4 days over which the sex products remain highly fertile, and hence that storage at 3 C will provide greater leeway than storage at 8–9 C in the time permissible between spawn collection and fertilization.

An important factor affecting the viability of the sex products under "dry" storage may be that of the opportunity for gaseous exchange. In our tests, the containers holding stored ova and milt provided a large air space relative to the volume of contents (2.5 ml of milt in 25-ml vials, 118 ml of ova in 946-ml jars), but were tightly capped. The milt–air interface area in the vials was 450 mm^2, and the ova–air interface in the jars was 6500 mm^2. Recently, Truscott et al. (1968) showed that fertilizing capacity of Atlantic salmon (*Salmo salar*) milt stored at 2–3 C in full, tightly capped vials was much less than that of milt kept under similar conditions in vials permitting gaseous diffusion through the cap. Rutter (1902) found that chinook salmon (*O. tschawytscha*) milt stored in open bottles for 24 hr fertilized 74% of the ova to which it was applied, whereas that kept in tightly corked vials for 24 hr fertilized none. Smith and Quistorff (1943) tested the fertilizing capacity of milt kept in full, tightly capped vials at 6.1–7.0 C. Chinook milt held 5 hr under these conditions produced a hatch of only 54.1% from treated ova; steelhead trout (*Salmo gairdnerii*) milt held 5 hr produced a hatch of only 0.3% from the treated ova. In contrast to the above results, Butcher (1944) maintained the fertilizing capacity of brown trout (*Salmo fario*) milt for 5 days by storing it at 2.2–3.3 C, covered with a layer of paraffin. Until the relationship between the stored products and the atmosphere to which they are exposed is better understood, practical application of our results probably should permit at least some contact of the stored ova and milt with the air.

Misses Pat Murphy and Janice Prest and Mrs. Linda Hungar assisted in the examination of the eggs resulting from the trials. The staff of the Scully Creek hatchery assisted with field tests and maintained the eggs during incubation.

Fisheries Research Board of Canada
Biological Station, Nanaimo, B.C.

F. C. WITHLER
R. B. MORLEY

Received for publication June 4, 1968.

REFERENCES

BUTCHER, A. D. 1944. Preliminary observations on the storage of the milt of trout. Australian J. Sci., **7**: 23–25.

RUTTER, C. 1902. Natural history of the Quinnat salmon. Bull. U.S. Bur. Fish., **22**: 65–141.

SMITH, R. C., AND E. QUISTORFF. 1943. Experiments with the spermatozoa of the steelhead trout, *Salmo gairdnerii*, and the chinook salmon, *Oncorhynchus tschawytscha*. Copeia, **3**: 164–167.

TRUSCOTT, B., D. R. IDLER, R. J. HOYLE, AND H. C. FREEMAN. 1968. Sub-zero preservation of Atlantic salmon sperm. J. Fish. Res. Bd. Canada, **25**(2): 363–372.

WITHLER, F. C., AND R. M. HUMPHREYS. 1967. Duration of fertility of ova and sperm of sockeye (*Oncorhynchus nerka*) and pink (*O. gorbuscha*) salmon. Ibid., **24**(7): 1573–1578.

Simplification of a Method of Computing Recruitment Rates

In a previous paper (Allen, 1966), a method was described for computing the proportion of new recruits in each year-class in each year's catch from the annual age composition. As described, this method computed successively: (1) the recruited proportion (U) of each year-class in each year, from the age-compositions; (2) the proportion (R) of new recruits in the recruited part of each year-class in each year, from the values of U; (3) the total proportion of new recruits in the catch as the sum of the products of the proportion of new recruits in the catch from each year-class (R) and the proportion of that year-class in the total catch (P).

Further study has shown that it is unnecessary to calculate U and that a great simplification is achieved by calculating R directly from the age composition data. In the original derivation, the basic quantity computed from the age distributions was B for each age-group each year, where B for the a^{th} age-group in year 1 in any pair of years was given by

$$B = \frac{P_{2,a+1} \cdot Q_{1,r}}{P_{1,a} \cdot Q_{2,a+1}} \qquad \ldots\ldots(1)$$

where $P_{1,a}$ = proportion in the catch of the a^{th} age-group (partly recruited) in year 1; $P_{2,a+1}$ = proportion in the catch of the $a+1^{th}$ age-group in year 2. $Q_{1,r}$ = proportion in the catch of all fully recruited age-groups from r up in year 1. $Q_{2,r+1}$ = proportion in the catch of all age-groups from $r+1$ up in year 2.

Writing $B_{1,a}$ for B, it was then shown that

$$U_{1,a} = \frac{e^{F_1}}{\frac{B_{1,a}}{TU_{2,a+1}} - 1 + e^{F_1}} \qquad \ldots\ldots(2)$$

and that

$$R_{2,a+1} = 1 - \frac{U_{1,a}}{U_{2,a+1}} \cdot \frac{1}{U_{1,a} + (1 - U_{1,a})\, e^{F_1}} \qquad \ldots\ldots(3)$$

where F_1 is the instantaneous fishing mortality rate in year 1.

It has now been found that rewriting equation 2 as

$$e^{F_1} = \frac{U_{1,a}}{U_{2,a+1}} \cdot \frac{B/T - U_{2,a+1}}{1 - U_{1,a}} \qquad \ldots\ldots(4)$$

and substituting in equation 3 gives

$$R_{2,a+1} = \frac{B_{1,a} - T}{B_{1,a}} \qquad \ldots\ldots(5)$$

J. Fish. Res. Bd. Canada, 25(12): 2701–2702, 1968.
Printed in Canada.

where T is the ratio of the overall survival rate of the recruited members of the partially recruited year-classes to the overall survival rate of the fully recruited year-classes. Commonly T may be taken as = 1.0. This simplified relationship also depends on the assumption which was involved in the original derivation of equation 2 that, even though the total mortality rate may vary considerably from year to year, it is unlikely that the relationship between the fishing mortality rate for new recruits and that for older animals will change appreciably from one year to the next, and that such changes may, therefore, be ignored.

Under the simple conditions defined by the above assumption and by putting T = 1.0, equation 4 can also be seen to follow directly from equation 1 since $B_{1,a}$ is a direct measure of the proportional change in abundance of the a^{th} age-group from year 1 to year 2, due to causes other than the natural and fishing mortalities which also affect the fully recruited part of the population.

The amended method of computing R simplifies the calculations in a number of ways. It eliminates the intermediate calculation of U, it removes the dependence on F, and the formula to be computed is considerably simpler than those in the original procedure. A still greater simplification is, however, introduced by the fact that each value of R is computed directly from a single value of B. Under the original procedure only the relation between $U_{1,a}$ and $U_{2,a+1}$ could be obtained from each value of B. To compute the array of values of U, it was, therefore, necessary to traverse the matrix diagonally from the oldest age-group in the last year, making assumptions as to the starting values of U for each diagonal.

Fisheries Research Board of Canada
Biological Station, Nanaimo, B.C.

K. RADWAY ALLEN

Received for publication August 12, 1968.

REFERENCES

ALLEN, K. RADWAY. 1966. Some methods for estimating exploited populations. J. Fish. Res Bd. Canada, **23**(10): 1553–1574.

Reproductive Isolating Mechanisms of the Blackspotted Stickleback, *Gasterosteus wheatlandi*

The family Gasterosteidae is represented in North America by four genera, of which all but *Gasterosteus* are monotypic. This genus includes the widely distributed three-spined stickleback *G. aculeatus* as well as the more locally occurring *G. wheatlandi*. Early in the taxonomic history of *G. wheatlandi* there was some question whether it was a full species or a geographic race of *G. aculeatus* (e.g., Goode and Bean, 1879). Later, the distinctive morphological features of this species were firmly established (e.g., Kendall, 1896). The common name "blackspotted stickleback" as adopted by Leim and Scott (1966) is preferred over the previously used "two-spined stickleback." The latter designation is a misleading description and often is confused with the synonym *G. bispinosus* (cf. Hubbs, 1929) which has been applied to both species of this genus.

Gasterosteus wheatlandi ranges from Quebec (McAllister, 1960a) and Newfoundland (Scott and Crossman, 1964) to the waters of Long Island Sound (Perlmutter, 1963). It is predominantly found in marine coastal waters but has been reported from fresh water (McAllister, 1960b). Collections for this study were made in the marine lagoon and tidal marshes of Reid State Park, Maine, on Oct. 1, 1967, and May 30, 1968. These collections also yielded specimens of other stickleback species (*Apeltes quadracus*, *Pungitius pungitius*, and *G. aculeatus*). Reproductively mature individuals of these four species were obtained only in the 1968 collection.

Male *G. wheatlandi* collected in the spring were placed in separate 5½-gal aquaria that contained fresh water fortified with 20 ppm calcium chloride, a fine gravel substrate, and filamentous green algae. The temperature ranged from 18 to 20 C under a photoperiod of 15 hr per day.

Five males were so treated, and all commenced nest-building activities within the 1st week. The base of the nests averaged approximately 3–4 cm in diameter and were indistinguishable in structure from *G. aculeatus* nests described in the literature. Because *G. wheatlandi* males (3.3 cm SL) were about 2 cm shorter than *G. aculeatus* males, the diameter of the nest base and the internal diameter of the nest tunnel were correspondingly smaller. No quantitative difference was apparent between nest-building activities of *G. wheatlandi* and published descriptions of *G. aculeatus* activities. All of the components, i.e., sand-digging, collection and manipulation of nest material, fanning, glueing, and creeping through, were observed in the same sequence and frequency as is commonly reported for *G. aculeatus* (van Iersel, 1953).

The two *Gasterosteus* species are often confused, and the observations of reproductive behavior in *G. wheatlandi* cited by Bigelow and Schroeder (1953) and Breder and Rosen (1966) are actually descriptions of *G. aculeatus*.

J. Fish. Res. Bd. Canada, 25(12): 2703–2706, 1968.
Printed in Canada.

The reproductive behavior and secondary sex characters of *G. wheatlandi* are similar to that of the well-studied *G. aculeatus* (Tinbergen, 1951), with the exception that the blackspotted stickleback does not display a zig-zag courtship dance and the male nuptial coloration involves a uniform metallic lemon-yellow color rather than a red venter. The female of both species is normally larger than the male (Perlmutter, 1963) and possesses a variable and relatively dull coloration. When a gravid female is placed in an aquarium in which a male *wheatlandi* has built a nest, the male courts her and leads her to the nest entrance by means of a display common to the nest-directed fanning behavior observed in this genus (Sevenster, 1961).

Upon the introduction of a female, the male commences his fanninglike courtship display close to where the female rests. This display is continued until the female orients herself behind and underneath the male; if this response is not elicited, the male butts her head region or bites at her tail. Nonreceptive females extend their ventral spines and flee from these attacks. The male may then either resume courtship or go to the nest and display nest-building activities, most commonly glueing and fanning.

The male courtship display can be distinguished from normal fanning activities by the duration of the display, which is longer, as well as by the fact that the pale orange ventral spines are extended. Although the initial bouts of this courtship activity are not necessarily oriented towards the nest, as soon as the female aligns herself beneath the male and between the extended ventral spines, the male turns and slowly moves towards the nest while continually vibrating his body in fanninglike activity. Unlike *G. aculeatus* males that display a zig-zag courtship dance followed by a leading movement towards the nest, the blackspotted stickleback display continues throughout the leading phase until the female is at the nest. The courtship display normally lasts for a few minutes unless the female is very responsive; when the female remains stationary and is not responsive, the courtship may last for 10–15 min. However, after a protracted courtship without female response, the male becomes more aggressive, and tail biting becomes frequent. Both the normal fanning and courtship activity occur in a slightly head-down posture, although as the male leads the female to the nest site his tail is also in a depressed position. This unique courtship display was confirmed by successively presenting the five males with the same female. This procedure resulted in identical patterns of the behavior.

When the sexual partners reach the nest site, the male places his snout in the entrance, moves back, and the female then enters, spawns as a result of the male running his snout along the sides of the female, and exits. The male then enters and quickly fertilizes the eggs. This consummatory act, as well as the male's attack on the deflated female and his commencement of nest-maintenance activities upon his exit, are similar to the behavior reported for *G. aculeatus*.

In the fall of the year, all of the stickleback species occurring in this area could be obtained at the same collection station. However, during the spring

this could not be done, a fact which suggests that the two *Gasterosteus* species tend to occur in slightly different habitats during the breeding season at Reid State Park. Furthermore, Perlmutter (1963) proposed that *G. aculeatus* approaches the end of its spawning period at a time when *G. wheatlandi* is just beginning. This is indicated by the predominant occurrence, in late spring, of 0-age *aculeatus* reported by Perlmutter and confirmed here.

The genus *Gasterosteus* comprises a multitude of intergrading forms, many of which have been designated subspecies of *aculeatus*. Hagen (1967) proposed the existence of ecological isolating mechanisms occurring between the marine and freshwater forms in British Columbia. This study suggests behavioral and other differences that could potentially restrict gene flow between *G. aculeatus* and *G. wheatlandi*. There is, however, no direct evidence that these differences are sufficient to prevent hybridization. Although preliminary evidence indicates that both of these species possess the same chromosome number ($n = 21$), they do differ in their "nombre fondamental" (T. R. Chen, personal communication). More detailed karyotype and electrophoretic blood serum analyses in progress may uncover other differences.

This investigation was supported by a postdoctoral fellowship from the National Institutes of Health. I would like to thank Dr Tom J. Cade, Cornell University, for his interest in this problem and for his helpful suggestions with the manuscript.

Division of Biological Sciences
Cornell University, Ithaca, N.Y.

HOWARD M. REISMAN

Received for publication August 19, 1968.

REFERENCES

BIGELOW, H. B., AND W. C. SCHROEDER. 1953. Fishes of the Gulf of Maine. U.S. Fish Wildife Serv., Fish. Bull. No. 74. Vol. 53. 577 p.

BREDER, C. M., JR., AND D. E. ROSEN. 1966. Modes of reproduction in fishes. The Natural History Press, Garden City, New York. 941 p.

GOODE, G. B., AND T. H. BEAN. 1879. Catalogue of the fishes of Essex County, Massachusetts including the fauna of Mass. Bay and the contiguous deep waters. Essex Inst., Bull. No. 11. 38 p.

HAGEN, D. W. 1967. Isolating mechanisms in threespine sticklebacks (*Gasterosteus*). J. Fish. Res. Bd. Canada, **24**(8): 1637–1692.

HUBBS, C. L. 1929. The Atlantic American species of the fish genus *Gasterosteus*. Occasional Papers, Museum Zool., Univ. Michigan, No. 200. 9 p.

IERSEL, J. J. A. VAN. 1953. An analysis of the parental behaviour of the male three-spined stickleback (*Gasterosteus aculeatus* L.). Behaviour, Suppl., **3**: 1–159.

KENDALL, W. C. 1896. Description of a new stickleback, *Gasterosteus gladiunculus*, from the coast of Maine. Proc. U.S. Natl. Museum, **18**: 623–624.

LEIM, A. H., AND W. B. SCOTT. 1966. Fishes of the Atlantic coast of Canada. Bull. Fish. Res. Bd. Canada, No. 155. 485 p.

McALLISTER, D. E. 1960a. Le *Gasterosteus wheatlandi*, nouvelle espèce de poisson pour la province de Québec. Le Naturaliste Canadien, **87**(5): 117–118.

1960b. The twospine stickleback *Gasterosteus wheatlandi* new to the Canadian freshwater fauna. The Canadian Field-Naturalist, **74**(4): 177–178.

PERLMUTTER, A. 1963. Observations on fishes of the genus *Gasterosteus* in the waters of Long Island, New York. Copeia, 1963(1): 168–173.

SCOTT, W. B., AND E. J. CROSSMAN. 1964. Fishes occurring in the fresh waters of insular Newfoundland. Dept. Fish. Canada, Ottawa, Ont. 124 p.

SEVENSTER, P. 1961. A causal analysis of a displacement activity (fanning in *Gasterosteus aculeatus* L.). Behaviour, Suppl., **9**: 1–170.

TINBERGEN, N. 1951. The study of instinct. Clarendon Press, Oxford. 228 p.

New Records of the Barnacle *Conchoderma virgatum* in the Northwest Atlantic

The pedunculate barnacle *Conchoderma virgatum* (Spengler) 1790, is widely known in the warmer waters of the world. Summary accounts of its occurrence have been provided by several authors including Bouxin and Legendre (1952), Ciurea et al. (1933), Clarke (1966), Cornwall (1955), Daniel (1956), Hiro (1937), and Jones et al. (1968). A further summary is given in contribution No. 580 from the Woods Hole Oceanographic Institution (1952). It has been found on buoys, ships' bottoms, various fish, turtles, and whales, and attached to parasitic copepods embedded in whales, sunfish, marlins, flyingfish, and swordfish. MacIntyre (1966) reported it attached to fish tags. This note lists previously unpublished attachment sites and gives data on the frequency of occurrence of the barnacle on swordfish in the northwest Atlantic.

Although considered a warm-water species, *C. virgatum* has been reported from Iceland, Greenland, Scotland, and Norway in the North Atlantic, a distribution which may be due in part to the movements of the carrier. The occurrence of apparently healthy specimens on Emerald Bank (Table I) indicates that the barnacle can survive in water as cool as 14 C.

Specimens of *C. virgatum* were observed by the author and his colleagues 31 times (Table I) between 1964 and 1968, while fishing with surface longlines in the area from Cape Hatteras to the Grand Banks. Twenty-three of the occurrences were on penellid parasites (*Penella* spp.) of swordfish (*Xiphias gladius*); two were on the bills of swordfish; one was inside the lower jaw of a mako shark (*Isurus oxyrinchus*); one was on the gill arch of a mako shark; two were on twine encircling the pectoral region of different blue sharks (*Prionace glauca*), and two were on fish hooks left in blue sharks presumably after previous capture by unknown longline vessels. On September 3, 1953, H. D. Fisher (personal communication) collected a single barnacle from the gill raker of an 870-cm basking shark (*Cetorhinus maximus*) stranded in Maces Bay, N.B.

The specimens examined ranged from 2 to 60 mm in total length, with clusters showing size variations similar to those mentioned by Jones et al. (1968) that suggested gregarious settlement by the larvae. MacIntyre (1966) concluded that in Australian waters this species can grow to approximately 40 mm (20 mm capitulum length) in 17 days after settlement.

The larger barnacles were generally bright blue with six brown, or purple, longitudinal stripes. One, however, had yellow stripes. In formalin the colours faded to brown or grey, or blue-grey. In nature, small individuals were almost colourless.

J. Fish. Res. Bd. Canada, **25**(12): 2707–2710, 1968.
Printed in Canada

TABLE I. Occurrence of *Conchoderma virgatum*.

Date	Area	*C. virgatum* No.	*C. virgatum* Size (*mm*)	Substratum	Carrier Species	Carrier Size (*cm*)	Water temp (*C*)	Collector
1964								
Sept. 23	Browns Bank	2	–	Penellid	Swordfish	99	–	J. S. Beckett
Oct. 14	Georges Bank	1	58	"	"	146	18	A. R. Emery
1965		4	18–51	"	"	227	20	J. S. Beckett
May 24	Off Virginia							
June 12	Off New Jersey	1	39	"	"	224	17	D. G. MacDonald
June 18	Off New Jersey	1	53	"	"	224	18	"
July 9	Georges Bank	2	–	"	"	123	20	"
Aug. 3	Grand Banks	1	60	"	"	222	15	J. S. Beckett
Aug. 3	" "	1	51	"	"	187	15	"
Aug. 5	" "	1	48	"	"	199	16	"
Sept. 30	Georges Bank	1	–	"	"	152	20	S. N. Tibbo
Sept. 30	" "	1	–	Jaw	Mako shark	102	20	"
Oct. 3	" "	24	16–36	Sword	Swordfish	96	–	"
1966								
July 3	Emerald Bank	1	–	Sword	"	250	16	G. Krystal
July 9	Emerald Bank	2+1	–	Penellid (2)	"	262	14	G. Krystal
Sept. 6	Grand Banks	1	–	"	"	–	18	L. A. Hemphill
Sept. 7	" "	1	26	"	"	213	18	"
Sept. 8	" "	2	37,39	"	"	85	18	"
Sept. 12	" "	1	36	"	"	186	15	"
Sept. 12	" "	2	28,37	"	"	187	15	"
1967								
April. 17	Off N. Carolina	13	22–39	Twine	Blue shark	134	21	J. S. Beckett
Apr. 18	Off N. Carolina	1	29	Penellid	Swordfish	104	21	"
June 18	Georges Bank	1	37	"	"	233	21	"
June 21	Off N. Carolina	3+2	–	" (2)	"	99	21	F. B. Davy
July 19	Grand Banks	3	41–51	"	"	195	17	D. A. Welsh
July 25	Grand Banks	1	–	Gill arch	Mako	–	20	D. A. Welsh
Sept. 6	Flemish Cap	28+	2–17	Twine	Blue shark	132	19	S. N. Tibbo
1968								
June 10	Georges Bank	43+	2–48	Hook	" "	177	22	J. S. Beckett
June 10	" "	43+	2–33	Hook	" "	208	20	"
Apr. 16	" "	1	46	Penellid	Swordfish	156	18	"
Aug. 3	Grand Banks	2	38,39	"	"	212	17	"
Aug. 5	Grand Banks	1	34	"	"	160	19	"

Groups of two or more barnacles were observed 14 times. One cluster, 23 barnacles in a tight group on the upper surface, and one on the loewr surface of the bill of a swordfish (Fig. 1C, D), had a volume of 35 cc. This cluster must have presented considerable water resistance, particularly during slashing motions of the fish; however, the swordfish (96 cm fork length) showed no evidence of impaired feeding. Another cluster, 13 in all, was found on a double loop of twine knotted around a blue shark, slightly anterior to its pectoral fins (Fig. 1A). The barnacles were grouped on the twine (Fig. 1B) at the angle of each pectoral fin immediately behind the gill slits. Twine knotted in a similar position around another blue shark supported 28 barnacles over 2 mm, the largest being 17 mm in total length. Two hooks found on blue sharks each carried 43 barnacles over 2 mm, attached singly or in groups of various numbers, the largest cluster containing 32 individuals.

In all, 1955 swordfish were examined between 1958 and 1968 but no barnacles were observed on the 579 fish examined before mid-September 1964. The significance of this is not known and does not appear to be explained by the expansion of the fishery to other areas and seasons which occurred about that time, as barnacles have subsequently been taken in the original area during comparable months.

Most barnacles (23 of the 25 instances involving swordfish) were attached to penellid parasites. The incidence was higher on large (over 200 cm fork length) than on small swordfish. Of those fish for which size data are available, 8 (5.3%) of 151 large swordfish had barnacles, whereas only 12 (1.2%) of 1015 small swordfish had them. This difference is due partly to a higher incidence of penellids on large swordfish (46.4 vs. 32.5%). However, even when only fish parasitized by penellids are considered, barnacle frequency was still higher on large fish (11.4 vs. 3.6%). The number of penellids on each parasitized swordfish was not recorded although seven were counted on one fish. The penellids with barnacles attached were generally large, 90–112 mm exposed length, excluding egg sacs, although one 30-mm penellid had two well-developed barnacles attached to it.

Although swordfish often carried several penellids, only twice (July 9, 1966 and June 21, 1967) were barnacles noted on more than one penellid embedded in the same swordfish. In one instance two barnacles were seen on one penellid and one barnacle on another. In the other instance, three and two barnacles respectively were attached to two of five penellids.

The records suggest a change in the frequency of occurrence of both penellids and barnacles with season and area, the higher values being recorded later in the season and in the more easterly areas (Table I). The differences in the frequency between areas and seasons are not sufficiently pronounced to support any conclusions regarding population differences, but their possible use as a "biological tag" should be explored further.

A number of persons read the manuscript and the helpful criticism provided by Messrs E. C. Jones and S. N. Tibbo and Drs J. C. Medcof, W. B. Scott, and D. G. Wilder in particular is gratefully acknowledged.

Fisheries Research Board of Canada
Biological Station, St. Andrews, N.B.

J. S. BECKETT

Received for publication July 12, 1968.

REFERENCES

BOUXIN, H., AND R. LEGENDRE. 1952. Présence de deux espèces de cirripèdes thoraciques sur les rayons branchiostèges d'un squale pèlerin. Bull. Soc. Zool. Fr., **77**: 119–124.

CIUREA, J., TH. MONOD, AND G. DINULESCO. 1933. Présence d'un cirripède operculé sur un poisson dulcaquicole européan. Bull. Inst. Oceanog. Monaco, No. 615. 32 p.

CLARKE, R. 1966. The stalked barnacle *Conchoderma* ectoparasitic on whales. Norsk Hvalfangst-tid., **55**(8): 153–168.

CORNWALL, I. E. 1955. Canadian Pacific Fauna. 10. Arthropoda. 10e. Cirripedia. Fish. Res. Bd. Canada, Ottawa, Ont. 49 p.

DANIEL, A. 1956. The Cirripedia of the Madras Coast. Bull. Madras Govt. Museum Nat. Hist. N.S., **6**(2): 1–40.

HIRO, F. 1937. Studies on Cirripedian fauna of Japan. II. Cirripeds found in the vicinity of the Seto Marine Biological Laboratory. Mem. Coll. Sci., Kyoto (B), **12**: 385–477.

JONES, E. C., B. J. ROTHSCHILD, AND R. S. SHOMURA. 1968. Additional records of the pedunculate barnacle, *Conchoderma virgatum* (Spengler) on fishes. Crustaceana, **14**(2): 194–196.

MACINTYRE, R. J. 1966. Rapid growth in stalked barnacles. Nature, **212**(5062): 637–638.

WOODS HOLE OCEANOGRAPHIC INSTITUTION. 1952. Marine fouling and its prevention. Contribution No. 580. Woods Hole, Mass. 388 p.

(FIG. 1 *opposite*)

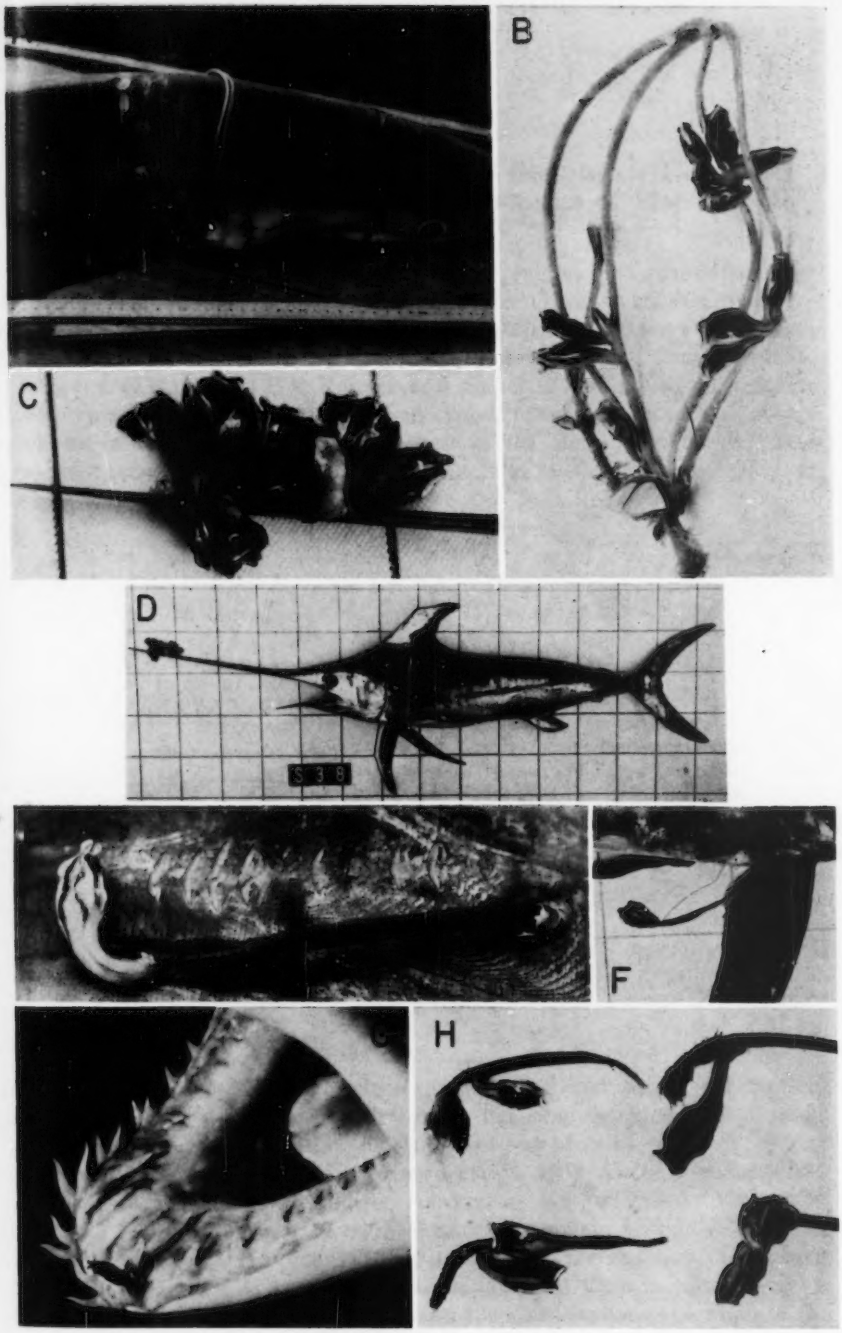


FIG. 1. A, blue shark (*Prionace glauca*) captured April 17, 1967, with twine to which were attached 13 specimens of *Conchoderma virgatum*; B, twine shown in A after removal from shark; C, tip of the sword shown in D with 24 specimens of *C. virgatum*; D, swordfish (*Xiphias gladius*) taken October 3, 1965; E, F, *C. virgatum* attached to penellid parasites of swordfish; G, *C. virgatum* attached to the lower jaw of a mako shark (*Isurus oxyrinchus*) taken October 30, 1965; H, four penellid parasites of swordfish with 1–4 specimens of *C. virgatum* attached.

Localization of Creatine Kinase in the Starch-Gel and Moving-Boundary Electrophoretic Patterns of Fish Muscle

The comparative study of fish sarcoplasmic proteins by moving-boundary electrophoresis has shown that a general pattern exists, characterized by the presence of several acidic components, amounting to a large proportion of the proteins soluble at low ionic strength (Henrotte, 1960; Connell, 1953a, b; Jebsen and Hamoir, 1958; Hamoir and Konosu, 1965). No counterparts to these components are found in a mammalian muscle tissue such as rabbit muscle as is suggested by the comparison of the electrophoretic diagrams of rabbit muscle and carp white muscle extracts at low ionic strength (Fig. 1)

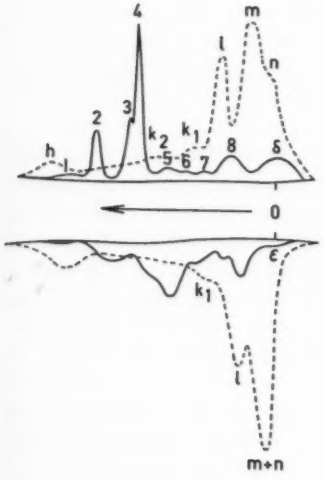


FIG. 1. Comparison of the ascending (*upper*) and descending (*lower*) moving-boundary electrophoretic patterns of adult carp (solid line) and rabbit (broken line) muscle extracts of low ionic strength at I 0.075 and *p*H 7.3.

and unequivocally proved by ultracentrifugation and starch-gel electrophoresis. For carp white muscle extracts, it has been established that peaks 1, 2, 3, and 5 correspond to low molecular-weight proteins to which no glycolytic activity can be assigned (Konosu et al., 1965; Pechère and Focant, 1965). Peak 4, which was crystallized many years ago and called "Myogen I" (Henrotte, 1952), is known to be a higher molecular-weight protein sedimenting at the rate of 5.0 S (Henrotte, 1960). Furthermore, the isolation of the components 2, 3, 4, and 5 as well as the determination of their molecular-weights (Konosu et al., 1965; Henrotte, 1960) and the quantitative separation of the

J. FISH. RES. BD. CANADA, **25**(12): 2711–2714, 1968.
Printed in Canada.

low molecular-weight proteins 1, 2, 3, and 5 by filtration on Sephadex G-75 leave no doubt about the identity of the moving-boundary peaks with the starch-gel bands (Fig. 2). On starch-gel electrophoresis at *p*H 7.2, peak 4 is relatively slowed down because of its size. However, at *p*H 8.4, its mobility is greatly increased indicating a high proportion of amino acid residues titrating in the *p*H range of 7.2–8.4 (Fig. 2).

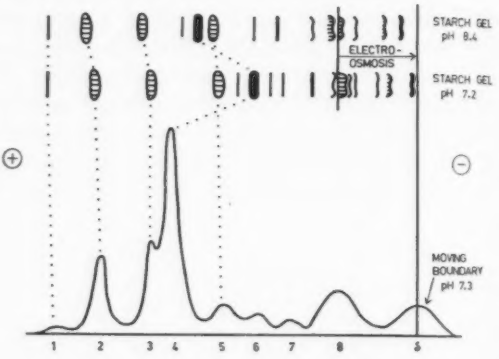


FIG. 2. Comparison of moving-boundary electrophoretic pattern of carp white muscle at I 0.075, *p*H 7.3, with starch-gel patterns in discontinuous buffer systems at *p*H 7.2 and 8.4 (Scopes, 1968).

We have now demonstrated that peak 4 is creatine kinase (2.7.3.2 ATP: creatine phosphotransferase). The enzyme activity was easily revealed on the starch-gel either through the back reaction (Sjörvall and Voigt, 1964) or by coupling the forward reaction with pyruvate kinase and lactate dehydrogenase to oxidise NADH; in this last instance, the enzyme is located at the clear area which appears when remaining NADH is made to reduce nitroblue tetrazolium (Scopes, 1968). Activity measurements have shown that the procedure used previously to isolate myogen I largely inactivates the enzyme.

In other fish species, a large electrophoretic component similar to carp component 4 is detected by the moving-boundary method, having a mobility of -3 to -4×10^{-5} cm^2 v^{-1} sec^{-1} at I 0.075 and neutral *p*H, namely 5 of cod (Connell, 1953a, b), 4 of plaice (Henrotte, 1960; Jebsen and Hamoir, 1958), and 3 of *Tilapia macrochir* (Piront et al., 1968). The components of plaice and *Tilapia* are salted out in the same range of 50–80% neutral ammonium sulphate saturation and at least a major fraction of them sediments at 5–5.5 S. Both carp component 4 and *T. macrochir* component 3 have the same isoelectric point, 5.4. Specific staining on starch gel has confirmed that the *Tilapia* component 3 is creatine kinase and that almost all of over 20 fish species have a strong creatine kinase band with a mobility on the starch-gel much greater than that of rabbit (Fig. 3) and other mammalians like ox (Scopes, 1964) and pig (Scopes, 1966). By analogy it would seem that the major part of the electrophoretic peaks of cod and plaice sarcoplasmic proteins mentioned above is creatine kinase.

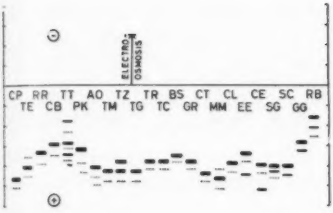


FIG. 3. Starch-gel patterns of white muscle extracts of fish and rabbit stained for creatine kinase. Migration, given in centimeters, after 4 hr electrophoresis at 20 v/cm in the cold, using a discontinuous system at *p*H 8.4. The abbreviations, from left to right, correspond respectively to carp (*Cyprinus carpio*), tench (*Tinca tinca*), roach (*Rutilus rutilus*), chub (*Leuciscus cephalus*), trout (*Salmo fario*), pike (*Esox lucius*), *Astronotus ocellatus*, *Tilapia macrochir*, *T. mossambica*, *T. guineensis*, *T. rendalli*, *T. tholloni congica*, black bass (*Micropterus salmoides*), gurnet (*Trigla gurnardus*), bullhead (*Cottus scorpius*), *Onos* (*Motella tricerratus*), codling (*Gadus callarias*), common eel (*Anguilla anguilla*), conger eel (*Conger conger*), sturgeon (*Acipenser sturio*), dogfish (*Scyllium canicula*), tope (*Galeorhinus galeus*), and rabbit (*Oryctolagus cuniculus*).

A fivefold purification of carp creatine kinase has been reached by acetone fractionation at 0 C within the range 45–55% (v/v) followed by DEAE-cellulose chromatography in Tris buffer *p*H 8.0. No further purification could be achieved, the preparations appearing homogeneous and usually showing one strong band on starch gel (see Scopes and Gosselin-Rey, 1968) with negligible contamination. Thus, in carp, the relative proportion of sarcoplasmic proteins that is creatine kinase appears much greater than in rabbit where it amounts to 5.7% of the sarcoplasmic proteins as indicated by Czok and Bücher (1960), though this is probably an underestimate. Nevertheless, the specific activity of creatine kinase in the sarcoplasm of carp is only 70% of that in the sarcoplasm of rabbit and the specific activity of the pure carp enzyme measured as described by Burger et al. (1964) is 35 μmole/min per mg protein at 30 C whereas the pure rabbit enzyme has an activity of about 120 μmole/min per mg protein under these conditions.

It appears then, that the carp creatine kinase and probably the enzyme from other fish, differ from the mammalian enzyme not only in having a lower isoelectric point, but also in having a lower specific activity. The latter fact is mostly compensated for by being present at a two to three times greater concentration relative to the other sarcoplasmic proteins.

Department of General Biology
Institute Ed. Van Beneden
University of Liège, Liège, Belgium

C. GOSSELIN-REY
G. HAMOIR

Agricultural Research Council
Meat Research Institute, Langford, Nr. Bristol

R. K. SCOPES

Received for publication April 17, 1968.

REFERENCES

BURGER, A., R. RICHTERICH, AND H. AEBI. 1964. Die heterogenität der kreatin kinase. Biochem. Z., **339**: 305–314.

CONNELL, J. J. 1953a. Studies on the proteins of fish skeletal muscle. 1. Electrophoretic analysis of codling extracts of low ionic strength. Biochem. J., **54**: 119–126.

1953b. Studies on the proteins of fish skeletal muscle. 2. Electrophoretic analysis of low ionic strength extracts of several species of fish. Ibid., **55**: 378–388.

CZOK, R., AND TH. BÜCHER. 1960. Crystallized enzymes from the myogen of rabbit skeletal muscle. Advan. Protein Chem., **15**: 315–415.

HAMOIR, G., AND S. KONOSU. 1965. Carp myogens of white and red muscles. General composition and isolation of low molecular weight components of abnormal amino acid composition. Biochem. J., **96**: 85–97.

HENROTTE, J. G. 1952. A crystalline constituent from myogen of carp muscle. Nature, **169**: 968.

1960. Contribution a l'étude des myogènes de carpe et de plie. Biochim. Biophys. Acta, **39**: 103–121.

JEBSEN, J. W., AND G. HAMOIR. 1958. Electrophoretic and ultracentrifugal study of plaice myogen. Acta Chem. Scand., **12**: 1851–1868.

KONOSU, S., G. HAMOIR, AND J.-F. PECHERE. 1965. Carp myogens of white and red muscles. Properties and amino acid composition of the main low molecular weight components of white muscle. Biochem. J., **96**: 98–112.

PECHERE, J.-F., AND B. FOCANT. 1965. Carp myogens of white and red muscles. Gross isolation on sephadex columns of the low molecular weight components and examination of their participation in anaerobic glycogenolysis. Ibid., **96**: 113–118.

PIRONT, A., G. HAMOIR, AND R. CROKAERT. 1968. Proteinic composition of the low ionic strength extracts of *Tilapia macrochir* Boulenger white muscles. Arch. Intern. Physiol. Biochim., **76**: 1–25.

SCOPES, R. K. 1964. The influence of post mortem conditions on the solubilities of muscle proteins. Biochem. J., **91**: 201–207.

1966. Isolation and properties of a basic protein from skeletal muscle sarcoplasm. Ibid., **98**: 193–197.

1968. Methods for starch-gel electrophoresis of sarcoplasmic proteins. An investigation of the relative mobilities of the glycolytic enzymes from the muscles of a variety of species. Ibid., **107**: 139–150.

SCOPES, R. K., AND C. GOSSELIN-REY. 1968. Polymorphism in carp muscle creatine kinase. J. Fish. Res. Bd. Canada, **25**(12): 2715–2716.

SJÖRVALL, K., AND A. VOIGT. 1964. Creatine-phospho-transferase isozymes. Nature, **202**: 701.

Polymorphism in Carp Muscle Creatine Kinase

It has been shown by starch-gel electrophoresis that the fish muscle creatine kinases are generally more anodic than their mammalian counterparts (Gosselin-Rey et al., 1968); the enzyme of the carp *Cyprinus carpio* is amongst the most mobile. However, occasional individuals contained a less mobile form of the enzyme in addition to the normal band. The intensity of staining of the two bands, either with nigrosine or with specific methods, indicated that each was present at about half the amount of the normal single band. Minor components, amounting in all to less than 5% of the total, which appeared after prolonged enzymic staining, are ignored for the present discussion. An illustration of the starch-gel patterns at *p*H 7.2 for each type is shown in Fig. 1. Out of 51 individuals, 8 were found to possess the two forms

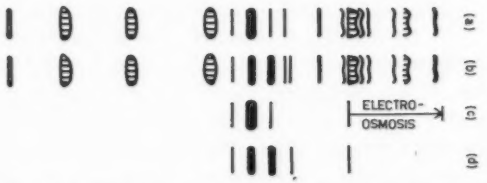


FIG. 1. Starch-gel patterns of carp white muscle sarcoplasmic proteins: (*a*) and (*b*) represent nigrosine staining; (*c*) and (*d*) are specific stains for creatine kinase; (*a*) and (*c*) are the homozygotes, and (*b*) and (*d*) the heterozygotes for creatine kinase. Electrophoresis was carried out for 4 hr at 20 v/cm with a discontinuous buffer system at *p*H 7.2

of creatine kinase. A simple polymorphism seems the obvious explanation, in which case, although no individual was found with the more uncommon band only, the sample size was too small to expect this. Most individuals originated from one small pond, but some others were included, thus the whole set is not representative of a genetically equilibrated population.

Much evidence has accumulated to indicate a two-subunit structure for mammalian and avian creatine kinase (Watts et al., 1962; Dawson et al., 1967; Yue et al., 1967). Presuming that the same structure applies to the carp enzyme, then if both subunits were identical in the homozygote, the heterozygote would exhibit three forms of the enzyme, assuming random combination of the subunits in vivo. In the cases of carp phosphoglucose isomerase and of *Tilapia guineensis* enolase, polymorphism resulting in either one or three bands was found (R. K. Scopes, unpublished data). Two bands were found in the presumed heterozygote of carp muscle creatine kinase, suggesting that either the normal homozygote enzyme consists of two non-identical subunits produced at separate genes, or that random combination of subunits does not apply in vivo in the carp muscle.

J. FISH. RES. BD. CANADA, **25**(12): 2715-2716, 1968.
Printed in Canada.

Although both mirror and common carp were examined, there was no evidence of a protein variant distinguishing the two breeds, and the creatine kinase heterozygote appeared in each with about the same frequency.

Several individuals from each of five species of the tropical percidiform genus *Tilapia* were also examined. Two electrophoretic mobilities of creatine kinase were found (A and B). Two species contained only the A form, two species only the B, but in *Tilapia mossambica*, one of the two individuals examined contained only B, and the other, both A and B. It would appear that polymorphism of creatine kinase occurs in this species also, and so may be quite common in fish.

R. K. Scopes is grateful for the facilities put at his disposal by the members of staff of the Institute Ed. Van Beneden during his short visit.

Agricultural Research Council
Meat Research Institute, Langford, Nr. Bristol
R. K. Scopes

Institute Ed. Van Beneden
University of Liège, Liège, Belgium
C. Gosselin-Rey

Received for publication April 17, 1968.

REFERENCES

Dawson, D. M., H. M. Eppenberger, and N. O. Kaplan. 1967. The comparative enzymology of creatine kinases. II. Physical and chemical properties. J. Biol. Chem., **242**: 210–217.

Gosselin-Rey, C., G. Hamoir, and R. K. Scopes. 1968. Localization of creatine kinase in the starch-gel and moving-boundary electrophoretic patterns of fish muscle. J. Fish. Res. Bd. Canada, **25**(12): 2711–2714.

Watts, D. C., B. R. Rabin, and E. M. Crook. 1962. The number of catalytic sites in creatine phosphokinase as determined by a study of its reactive sulphydryl groups. Biochem. J., **82**: 412–417.

Yue, R. H., R. H. Palmieri, O. E. Olson, and S. A. Kuby. 1967. Studies on adenosine triphosphate transphosphorylases. V. Studies on the polypeptide chains of the crystalline adenosine triphosphate-creatine transphosphorylase from rabbit skeletal muscle. Biochemistry, **6**: 3204–3227.

Upper Lethal Temperatures at Various Levels of Salinity in the Euryhaline Cyprinodontids *Fundulus heteroclitus* and *F. diaphanus* after Isosmotic Acclimation

Displacement of the lethal temperature of fishes by various metabolic stresses has been described by Brett (1958). Demonstrations of changes in the lethal level for temperature induced by the imposition of osmoregulatory stress began with the finding of Loeb and Wasteneys (1912) that the level of lethal temperature and the resistance time could be altered when an undesignated species of *Fundulus* (invariably identified as *F. heteroclitus* in the literature) was exposed to potentially lethal temperatures in media of various salinities. In spite of the obvious significance of those findings to such considerations as adaptation, distribution, and physiologic descriptions, rather little subsequent experimental attention has been alloted to this response. Summaries of the occasional studies of subsequent investigators are presented by Arai et al. (1963) and by Strawn and Dunn (1967).

The present study, besides considering the use of lethal temperature as a parameter for physiologic descriptions of the cyprinodontids banded killifish (*Fundulus diaphanus* (LeSueur)) and mummichog (*F. heteroclits* (L.)); examines the proposition that the lethal temperature for a given level of thermal acclimation is highest in isosmotic medium. Banded killifish occur most commonly in fresh waters but along the coastal boundary of its range it occasionally frequents estuaries. Mummichog, in contrast, habituate tidal bays, saltmarshes, and estuaries, venturing upstream rather infrequently. To compensate for the inequality in the salinities of the customary habitats, both species were brought to a common acclimation, 14‰ salinity, the approximate isosmotic level for the blood of *Fundulus* (Doudoroff, 1945). Subsequently, isosmotic baths served as the control medium for lethal tests which were conducted also in fresh water and in sea water, for both species.

Methods. — Quantities of mummichog and banded killifish were collected from various coastal and inland waters of Halifax Co., Bras d'Or Lake on Cape Breton Island, and Kedge Lake, Annapolis Co., Nova Scotia, during late summer, 1967. They were maintained, subsequently, in a laboratory at Dalhousie University for several weeks in glass aquaria, the contents of which were maintained at levels of salinity approximately that of previous natural habitats of the several collections. Each aquarium was equipped with a conventional aerating aquarium filter. Water was changed at 5–7-day intervals depending on the extent of fouling. Both species were fed a daily surfeit of a prepared diet "Tetramin." The laboratory was illuminated continuously to provide constancy and to promote maximum utilization of food.

Three weeks prior to the intended commencement of lethal tests these fish were transferred to water having a level of salinity of 14‰, with intervening levels of 20‰ for mummichog and 8‰ for killifish for 5 days. The level of 14‰

J. Fish. Res. Bd. Canada, 25(12): 2717–2720, 1968.
Printed in Canada

of salinity was maintained for both species through the balance of the period of acclimation. Simultaneously, water temperature was adjusted to 15 C by thermostatic regulation of room temperature and, when necessary, by thermostatically controlled immersion heaters, the metallic elements of which were covered with closely applied Tygon tubing.

Three consecutive series of lethal tests were conducted with each species, one at each of three levels of salinity (0, 14 (isosmotic mixture), and 32‰ (sea water)). Tests were conducted, usually at intervals of 1 degree C, from 35 C downward to levels which caused less than 50% mortality in 10,000 min. Several additional tests were performed, either confirmatory repetitions or tests at certain half-degree intervals.

Lethal tests were conducted in four 40-liter glass aquaria, each divided transversely with a screen of fine polyvinyl mesh which would permit complete circulation of water between the two equal compartments. Each aquarium was equipped with an aerating filter, an additional air diffuser to provide thorough circulation, and a 300-w calrod immersion element enclosed in Tygon tubing and controlled by a Jumo thermoregulator which adequately controlled temperature within ±0.1 degree C of the desired level. The laboratory was illuminated continuously. Fish in test aquaria were fed twice each day.

Each test was conducted simultaneously on both species, exposed to a designated constant temperature. In a single test, five of each species, unselectively removed from acclimation aquaria, were placed separately in the two compartments of a test aquarium. Continuous watch was maintained during the initial 600 min of exposure and intermittent watch thereafter. The time of death for each fish was recorded either from direct observation of death or from the time of the half-interval between the times of observation during which the fish had died. Individuals which survived the exposure were not employed in a subsequent test.

The length and the weight of each of the dead were recorded and each specimen was preserved separately.

Results. — Lethal temperatures were ascertained by inspection as the least temperature, at each level of salinity, at which at least 50% of the sample died within 10,000 min.

Highest upper lethal temperatures were observed in the isomotic medium, 33.5 C for banded killifish and 34.0 C for mummichog (Table I). There was a depression of 6 degrees C in the lethal temperature of banded killifish tested in fresh water and again in those tested in sea water. Depression of the lethal temperature of mummichog was also 6 degrees C in fresh water but tolerance was considerably greater in sea water where the level was 31.5 C, 4 degrees C higher than the corresponding level for banded killifish.

Inspection of scatter diagrams (not presented here) indicated that no trends exist between resistance times and the lengths and the weights of individuals in pooled data for each species.

Discussion. — Stress generated by compensatory osmoregulative processes and dysfunctions has been shown to influence rather substantially the tem-

TABLE I. Upper lethal temperatures for samples of banded killifish, *Fundulus diaphanus*, and mummichog, *F. heteroclitus*, acclimated in isosmotic medium (14‰) at 15 C and tested in three levels of salinity (0 (distilled water), 14, and 32‰ (sea water)). Exposure was 10,000 min in each test. Temperature marked (*) was established by interpolation.

Species	Lethal temp (*C*)		
	0‰	14‰	32‰
Banded killifish (*Fundulus diaphanus*)	27.5*	33.5	27.5
Mummichog (*Fundulus heteroclitus*)	28.0	34.0	31.5

perature which is lethal to both mummichog and banded killifish. Osmotic stress can be considered minimal in isosmotic medium and to increase progressively in either increasingly hyposmotic or hyperosmotic media. Results for banded killifish indicate that, with a thermal acclimation of 15 C, the stress imposed by such osmotic dysfunction is approximately equal in its regulation of the lethal effect of temperature whether osmotic imbalance is that of dilution or of dehydration of protoplasm. Below 27.5 C presumably osmoregulation proceeds at least adequately and maintenance of cytoplasmic and membrane stability contributes positively to viability. Mummichog react to the diluting effect of the hyposmotic medium, approximately to the same extent as do banded killifish. However, mummichog have a measurably greater capacity for regulation against the dehydrating hyperosmotic medium as indicated by the lethal temperature which is intermediate relative to those for hyposmotic and isosmotic media.

Our findings fit the general trend exhibited by seven species of euryhaline cyprinodontids, two poecillids, and a centrarchid from Texas salt marshes, tested by Strawn and Dunn (1967), although their procedure differed somewhat. Fish in the latter experiments were acclimated to a salinity of 5‰, well below the isosmotic level. Nevertheless, highest lethal temperatures occurred in approximately isosmotic salinities of 12 ± 2‰. The more complex findings of Gibson (1954) and Arai et al. (1963), using the guppy *Lebisters reticulatus*, also provide a suggestion of this trend. Reports by Craigie (1963) and Alabaster (1967) for salmonids indicate that lethal temperatures are elevated in saline media, even below isosmotic concentrations, relative to those temperatures for fish tested in fresh water.

Much remains to be investigated at various combinations of temperatures and salinities before adequate physiologic descriptions can be advanced. However, even at the present level of study the basis for the primary ecologic separation which exists between these species might be explained at least partially by differential responses to salinity particularly during intense insolation and heating of shallow ponds and marshes in summer.

Financial support for this study was drawn from an operating grant provided by the National Research Council of Canada.

Department of Biology
Dalhousie University, Halifax, N.S.

E. T. GARSIDE
C. M. JORDAN[1]

Received for publication August 12, 1968.

REFERENCES

ALABASTER, J. S. 1967. The survival of salmon (*Salmo salar* L.) and sea trout (*S. trutta* L.) in fresh and saline water at high temperatures. Water Res., **1**: 717–730.

ARAI, M. N., E. T. COX, AND F. E. J. FRY. 1963. An effect of dilutions of seawater on the lethal temperatures of the guppy. Canadian J. Zool., **41**: 1011–1015.

BRETT, J. R. 1958. Implications and assessments of environmental stress. *In* Investigations of fish-power problems. Univ. British Columbia Press, Vancouver, B.C. p. 69–83.

CRAIGIE, D. E. 1963. An effect of water hardness in the thermal resistance of the rainbow trout, *Salmo gairdnerii* Richardson. Canadian J. Zool., **41**: 825–830.

DOUDOROFF, P. 1945. The resistance and acclimatization of marine fishes to temperature changes. II. Experiments with *Fundulus* and *Atherinops*. Biol. Bull., **88**: 94.

GIBSON, M. B. 1954. Upper lethal temperature relations of the guppy, (*Lebistes reticulatus*). Canadian J. Zool., **32**: 393–407.

LOEB, J., AND H. WASTENEYS. 1912. On the adaptation of fish (*Fundulus*) to higher temperatures. J. Exptl. Zool., **12**: 543.

STRAWN, K., AND J. E. DUNN. 1967. Resistance of Texas salt- and freshwater-marsh fishes to heat death at various salinities. Texas J. Sci., **19**: 57–76.

---

[1]Present address: Fisheries Division, Ministry of Agriculture, Land and Fisheries, Port of Spain, Trinidad.

First Occurrence of Greenland Halibut (*Reinhardtius hippoglossoides*) in the Bay of Fundy

Two specimens of the Greenland halibut were taken during March 1968 in the Bay of Fundy (45°05′30″N lat, 66°44′30″W long). They were captured alive in an otter trawl towed by the M.B. *Mallotus* at a depth of 15–25 fath (27–46 m).

The specimens, which are stored (Cat. No. ROM 25,989) at the Royal Ontario Museum, Toronto, Ont., are 270 mm and 419 mm in total length. The description of these specimens agrees with those published by Bigelow and Schroeder (1953) and Leim and Scott (1966). Our specimens also agree with those of Boyar (1964) in having a markedly light grey blind side, which does not approach the darkness described by Jensen (1925).

The distribution of this species in the Arctic and North Atlantic is well documented. A substantial fishery is located off the coast of Newfoundland and Labrador. Leim and Scott (1966) have listed its southern-most range as extending to New Jersey. This is based upon what appears to be an erroneous interpretation of Breder (1929). The reference to range in Breder's work applies to the Atlantic halibut, *Hippoglossus hippoglossus*, and not *Reinhardtius hippoglossoides*.

The Greenland halibut in the western Atlantic is considered to be a deep-water form even in its northern range. Leim and Scott (1966) record a depth range of 70–350 fath (127–637 m); Bigelow and Schroeder (1953) extend this down to 530 fath (965 m) and Boyar (1964) indicates a depth range down to 600 fath (1092 m).

The occurrence of Greenland halibut in the Bay of Fundy and in such shallow waters has not been recorded before. Boyar (1964) recorded four specimens from the Gulf of Maine and extended the known shoal water (vertical) range to 35 fath (64 m). Three of his four specimens were of the same general size (261, 272, 264 mm) as the smallest of the Bay of Fundy specimens, with the fourth specimen slightly longer (320 mm). The larger Bay of Fundy specimen was nearly 100 mm longer than the largest Gulf of Maine specimen. The Bay of Fundy specimens were taken with large quantities of the shrimp *Pandalus montagui* Leach, and examination of the gut contents of the larger specimen revealed specimens of *Crangon* and *Pandalus*.

Temperatures and salinities for this area were recorded in February and March 1968, the bottom temperatures being 1.0 and 0.8 C respectively. These temperatures were the coldest recorded since 1959 and, prior to that, 1948. Salinities were quite stable at nearly 32‰ and indicated a complete mixing of waters along with little freshwater runoff.

Thus, these environmental conditions in the shallow waters of this region more nearly approached that of the normal environment for the Greenland

J. Fish. Res. Bd. Canada, 25(12): 2721–2722, 1968.
Printed in Canada.

halibut. The low temperatures, higher and stable salinities, and large concentrations of food would all be contributing factors in the rare occurrence of this species in the Bay of Fundy.

Fisheries Research Board of Canada
Biological Station, St. Andrews, N.B.

B. E. BARRETT

Received for publication August 2, 1968.

REFERENCES

BIGELOW, H. B., AND W. C. SCHROEDER. 1953. Fishes of the Gulf of Maine. U.S. Fish Wildlife Serv., Fish. Bull., 53(74): 577 p.

BOYAR, H. C. 1964. Occurrence of the Greenland halibut *Reinhardtius hippoglossoides* (Walbaum), in shallow waters in the Gulf of Maine. Copeia, 1964(1): 232–233.

BREDER, C. M., JR. 1929. Field book of marine fishes of the Atlantic coast. 2nd ed., revised 1948. G. P. Putnam's Sons, New York. 332 p.

JENSEN, AD. S. 1925. On the fishery of the Greenlanders. Medd. Komm. Havundersøgelser, Ser. Fiskeri, 7(7): 1–39.

LEIM, A. H., AND W. B. SCOTT. 1966. Fishes of the Atlantic coast of Canada. Bull. Fish. Res. Bd. Canada, No. 155. 485 p.

Lobsters from 95 Fath Deep off St. John's, Newfoundland

Lobsters (*Homarus americanus*) have been fished for some years on the continental slope at depths of about 150 fath mostly near Georges Bank (Schroeder, 1959). Various sizes of lobsters in catches indicate large, self-propagating populations of lobsters in this area. Surveys have indicated that the species may occur also but in comparatively smaller numbers in deep water from Georges Bank northward to the Nova Scotian Banks (McKenzie, 1966). No lobsters have been reported from the deep water immediately south of the Grand Banks of Newfoundland. Schroeder (1959), however, lists a few records supplied by W. Templeman of lobsters taken in trawling near Newfoundland. These were (*a*) from 6 miles off Cape Race in 24–30 fath, (*b*) from the Grand Banks in 43 fath, and (*c*) from near St. Pierre in 90 and 30 fath.

In recent years after the introduction of cod gillnets, occasional large lobsters weighing 3–5 lb (1–2 kg) have been taken entangled in these nets at about 95 fath (174 m) during commercial fishing in the autumn and winter off St. John's, Newfoundland. Four lobsters were caught in this way near Cape Spear about 3 miles (5 km) south of the Harbour of St. John's in December 1967. Also one lobster was caught off Cape Spear in autumn 1967 and one lobster off Sugar Loaf about 3 miles northeast of St. John's Harbour in 60 fath (110 m) in autumn 1967. Several other captures of lobsters during winter fishing for cod in deep water in 1966 and 1967 were reported without reference to date.

One large lobster was brought to the Biological Station in the winter of 1968. It had been taken on February 26 near Cape Spear (47°32′N lat, 52°36′W long) in 95 fath. It was a female 130 mm (5.1 inches) in carapace length with a calculated weight of about 4 lb (2 kg). It was nonovigerous but had large ova in the ovaries and would probably spawn in the summer of 1968 in spite of temperatures near 0 C at all times in the area and depth. Its stomach contents were fragments of the spider crabs *Hyas* and *Chionocetes*, fragments of shell of the whelk *Neptunea*, one small whole but eroded gastropod shell, four small opercula of gastropods, and also a few small fish bones and a few pieces of seaweed (*Ptilota*).

Lobsters have not been reported previously from deep water near the Newfoundland coast. Even the relatively shallow banks, 15–25 fath (25–44 m) deep, close to productive lobster grounds in western Newfoundland, do not appear to have lobsters. No lobsters were caught by the C.G.S. *Parr* during experimental fishing in May and June 1964 on grounds off Long Point (Port au Port Bay) and off Bay of Islands both at depths of 15–25 fath. Grounds at about 20 fath deep off Cow Head were also fished unsuccessfully for lobsters by Mr W. O. Swimm, a lobster buyer from Clark's Harbour, N.B. now living at Cow Head, Newfoundland (personal communication).

J. Fish. Res. Bd. Canada, 25(12): 2723–2724, 1968.
Printed in Canada.

Generally, very low temperatures of the water at intermediate depths or in the deep channels off the Newfoundland coast would deter lobsters from migrating into deep water from their shallow inshore grounds. Also the characteristic habit or life pattern of inshore lobster populations in Newfoundland apparently causes them to remain in shallow water, at least when they are not larger than the usual commercial sizes. Evidence from recent unpublished studies of one of us (G.P.E.) in Bonavista Bay, for example, indicates that migrations of lobsters to and from shallow and relatively deep water there are negligible even with changes in temperature and season. Since lobsters off St. John's were captured only a mile from the nearest shore, they may have migrated to deep water when temperatures in shallow water were similar to those in deep water, a condition which is often present in winter in this area. Lobsters of the east coast of the Avalon Peninsula are few in number and they are not fished commercially. Some of them, therefore, grow large and apparently wander away from the small area of shallow lobster grounds into deep water in search of food and shelter. There is no evidence from catches that a lobster population of various sizes is being built up in deep water in this area.

The area off St. John's where the lobsters were caught has an abundant population of queen crab, *Chionocetes opilio*. Gillnets set for cod often catch many of these crabs. Other predators on the crabs besides lobsters are chiefly cod (*Gadus morhua*), Greenland halibut (*Reinhardtius hippoglossoides*), and American plaice (*Hippoglossoides platessoides*).

We would like to thank Mr W. Smith of the Department of Fisheries of Canada (Bait Service) at St. John's for calling our attention to this occurrence, and several fishermen of St. John's who gave information.

Fisheries Research Board of Canada
Biological Station, St. John's, Nfld.

H. J. SQUIRES
G. P. ENNIS

Received for publication June 4, 1968.

REFERENCES

McKENZIE, R. A. 1966. Offshore lobster investigations, 1965. Canadian Fish. Rept. No. 6. p. 4–32.

SCHROEDER, W. C. 1959. The lobster, *Homarus americanus*, and the red crab, *Geryon quinquedens*, in the offshore waters of the western North Atlantic. Deep-Sea Res., 5: 266–282.

Overwintering of American Lobsters, *Homarus americanus*, in Burrows in Bideford River, Prince Edward Island

During a long-term survey, mainly by scuba, of benthos in the Bideford River estuary in Prince Edward Island, American lobsters (*Homarus americanus* Milne Edwards) were observed to overwinter in burrows in the mud. Others have reported that, on rocky bottom, both European and American lobsters burrow under rocks and on smooth sand may dig saucer-shaped depressions. (Dybern et al., 1957; McLeese and Wilder, 1964.) Herrick (1909) described burrows in mud banks of lobster pounds. However, excavation and seasonal occupation of burrows in estuarine mud has not previously been reported.

Lobsters are not common in the estuary during the summer, probably because temperatures rise close to their lethal range. During the spring fishing season, commercial catches for the estuary area, which comprises just over 135 ha, have averaged 570 kg/year over the last 5 years. Lobsters were observed during the late spring and summer to be confined to water over about 4 m deep, and normally inhabited excavations under rocks or other objects on the bottom. In the fall lobster populations in the estuary increased and many moved to shallower water along the sides and excavated burrows in the muddy bottom. These burrows were occupied until early spring, when the lobsters moved back to deeper water.

During 1965–67 an attempt was made to determine when, and under what temperature conditions, burrows were constructed, occupied, and vacated. Burrowing sites were visited on numerous occasions during the open water season (Table I). Lobsters dug burrows in the fall when temperatures fell

TABLE I. Observations on burrowing by American lobsters in Bideford River, P.E.I.

Date	Bottom temp (*C*)	Observations
May 1, 1965	5.0	Burrows empty.
June–Sept. 1965		Four surveys — burrows empty.
Oct. 15, 1965	7.0	Burrowing in progress.
Nov. 8, 1965	1.5	Burrows occupied, lobsters inactive.
Apr. 25, 1966	7.0	Burrows empty.
May–Oct. 1966		Eight surveys — burrows empty.
Nov. 11, 1966	8.0	Burrowing in progress.
Nov. 22, 1966	1.3	Burrows occupied, lobsters inactive.
Dec. 11, 1966	4.5	Burrows occupied, lobsters inactive.
May. 23, 1967	2.0	20% of burrows occupied.
June–Sept. 1967		Three surveys — burrows empty.

J. FISH. RES. BD. CANADA, 25(12): 2725–2727, 1968.
Printed in Canada.

below about 10 C. In the spring burrows appeared to be vacated when temperatures started to rise. Ice conditions hampered observations at this season.

Burrows were observed over several hectares of sloping bottom at depths of 1.3–4 m at mean low water. Bottoms were of mud containing varying amounts of sand and shell. The burrows sloped down into the bottom at about 15° to the horizontal and were roughly circular in cross section, having a diameter about twice that of the lobster (Fig. 1). Lengths of burrows varied, many exceeding 30 cm. In one area examined in detail in 1966, burrows were spaced about 2 m apart. Burrows were apparently used for only one season. Most collapsed during the summer and were not re-used. Excavated material formed a characteristic mound or platform at the burrow mouth; such structures from old burrows are common.

Most lobsters observed in burrows were facing the opening, but a few lacking claws were reversed. Most lobsters examined were close to the legal size limit of 6.4 cm carapace length but a few larger and smaller specimens were also present. The majority lay about 8–16 cm back in the burrow but some were much further in. Many were covered with a layer of silt (Fig. 1) indicating negligible activity. On Nov 22, 1966, the majority were in this condition and made little defensive movement when burrows were approached. Earlier, when burrows were being constructed, they were energetically defended; when approached lobsters moved forward to the burrow mouth with claws raised and open.

Superficially it would seem that the estuary might provide a rather unstable environment for lobsters, which, as shown by McLeese (1956), are unable to withstand very low salinities. Lobsters acclimated to water of 30‰ S by McLeese were unable to withstand salinities below 6‰, even under optimum temperature and oxygen conditions. Observations at Ellerslie, however, have shown that in winter salinities are generally high and stable at depths at which lobsters burrow. Exceptional weather conditions may result in a freshwater layer deep enough to cover burrows. This occurred in early May 1967 and mortalities of lobsters in some of the shallower burrows were observed (Thomas and White, 1969).

Lobsters are not alone in overwintering in burrows in estuarine mud. Similar behavior is exhibited, for example, by the American eel (*Anguilla rostrata* (Le Sueur)). The survival value of this behavior remains to be explained.

Fisheries Research Board of Canada
Oyster Unit, Ellerslie, P.E.I.

M. L. H. THOMAS[1]

Received for publication June 10, 1968.

[1]Present address: Fisheries Research Board of Canada, Marine Ecology Laboratory, Bedford Institute, Dartmouth, N.S.

(FIG. 1 and REFERENCES *follow*)

FIG. 1. Lobster burrow in a mixture of mud and shell in 3 m of water in Bideford River, Prince Edward Island, November 1965.

REFERENCES

DYBERN, B. I., L. JACOBSSON, AND H. HALLBACK. 1957. On the habitat behavior of the lobster (*Homarus vulgaris*) in Swedish waters. Medd. Havfiskelab. Lyskil, No. 36. 12 p.

HERRICK, F. H. 1909. Natural history of the American lobster. Bull. U.S. Bur. Fish., **29**: 149–408.

MCLEESE, D. W. 1956. Effects of temperature, salinity and oxygen on the survival of the American lobster. J. Fish. Res. Bd. Canada, **13**(2): 247–272.

MCLEESE, D. W., AND D. G. WILDER. 1964. Lobster storage and shipment. Bull. Fish. Res. Bd. Canada, No. 147. 69 p.

THOMAS, M. L. H., AND G. N. WHITE. 1969. Mass mortality of estuarine fauna at Bideford, P.E.I. associated with abnormally low salinities. J. Fish. Res. Bd. Canada, **26**(2). (In press.)

Occurrences of the Staghorn Sculpin (*Gymnocanthus tricuspis*) in Newfoundland Waters

A single specimen of the staghorn sculpin *Gymnocanthus tricuspis* (Reinhardt) was taken by the author while scuba diving in about 30 ft of water in Cape Broyle harbour on November 25, 1966 (in 47°05′N lat, 52°54′W long) (Fig. 1). Four other specimens from the Newfoundland area are in the collections of the Fisheries Research Board of Canada, Biological Station,

FIG. 1. Newfoundland, showing places mentioned in the text and the occurrences of the staghorn sculpin *Gymnocanthus tricuspis* in Newfoundland waters.

St. John's, Nfld. Three of these were taken by A. M. Fleming in a single set while beach seining for young cod in shallow water on the north shore of Southwest Arm, Random Sound, Trinity Bay, October 3, 1960 (48°03′N lat, 53°40′W long); the other was taken by otter trawl in deep water (over 50 fath) in St. Mary's Bay, October 16, 1949 (46°50′N lat, 53°47′W long). The only previous record for this species in Newfoundland waters was reported by Jeffers (1932) who found two specimens washed ashore on a beach at Raleigh, near the Strait of Belle Isle, August 9, 1930.

The two gravid females taken October 3, 1960, and the one spent female taken November 25, 1966, (Table I) indicate that the species is a fall spawner and that it probably spawns in these waters. The latter specimen is also interesting in that it is slightly larger than the maximum size of 10 inches for the species as recorded by Leim and Scott (1966).

Recorded catches of the staghorn sculpin in Newfoundland waters are few and scattered. During 1965–68 I collected nearly 1500 sculpins of four

J. FISH. RES. BD. CANADA, 25(12): 2729–2731, 1968.
Printed in Canada.

TABLE I. Data on newly recorded specimens of *Gymnocanthus tricuspis* for the Newfoundland area.

Area	Date	Total length (*cm*)	Sex	Maturity	Fin ray formula				
					D1	D2	Anal	Pectoral	Pelvic
St. Mary's Bay	Oct. 16, 1949	13.2	M	–	XI	16	17	19	3
Random Sound	Oct. 3, 1960	17.0	M	–	XI	15	16	18	3
" "	"	19.4	F	Gravid	XI	15	17	19	3
" "	"	23.0	F	Gravid	XI	15	17	18	3
Cape Bryole	Nov. 25, 1966	26.8	F	Spent	XI	16	18	19	3

species in these waters, mostly while scuba diving. Collections were made on the west coast from Bay St. George to St. John Bay, and on the east coast in Bonavista Bay and around the Avalon Peninsula. In addition I have examined many sculpins caught by fishermen. The one mentioned is the only specimen of *Gymnocanthus tricuspis* I have collected. Also, from 1959 to 1964, during a beach-seining survey for young cod that was conducted by A. M. Fleming and that extended from Notre Dame Bay southward into St. Mary's Bay, only three of hundreds of sculpins caught were staghorns. In Newfoundland waters the species is uncommon and appears to be on the fringe of its southern distribution limit. Further evidence of the subarctic nature of this species is the fact that the Newfoundland shallow-water records are from the north and east coasts, which are under the influence of the Labrador Current.

I am grateful to A. M. Fleming for bringing the specimens in this Station's collections to my attention.

Fisheries Research Board of Canada G. P. Ennis
Biological Station, St. John's, Nfld.

Received for publication June 24, 1968.

REFERENCES

Jeffers, G. W. 1932. Fishes observed in the Strait of Belle Isle. Contrib. Canadian Biol. Fish., N.S., 7(16): 203–211.

Leim, A. H., and W. B. Scott. 1966. Fishes of the Atlantic Coast of Canada. Bull. Fish. Res. Bd. Canada, No. 155. 485 p.

First Records of the Sculpins *Myoxocephalus thompsonii* and *Cottus ricei* from the Ottawa Valley, Southwestern Quebec

During a study on rainbow smelt, *Osmerus eperlanus mordax*, from 1964 to 1967, in the Ottawa Valley lakes, the first author obtained many cold-water species (*Percopsis omiscomaycus*, *Coregonus artedii*, and others), from 1–1½ inch stretched mesh gillnets. These included two species of freshwater sculpins hitherto unreported from the area.

In Heney Lake, Gatineau County, (75°54′–75°57′ long, 45°59′–46°04′ lat, see Fig. 1) nine specimens of the deepwater sculpin, *Myoxocephalus*

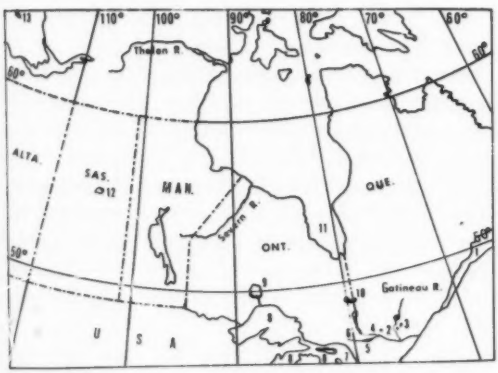


FIG. 1. Heney and Pemichangan lakes, relative to other localities in Canada from which *M. thompsonii* and *C. ricei* have been recorded. The numbers refer to: 1, St. Lawrence River; 2, Heney lake; 3, Pemichangan Lake; 4, Ottawa River; 5, Cedar Lake; 6, Petawawa River; 7, Georgian Bay; 8, lakes Huron, Michigan, and Superior; 9, Lake Nipigon; 10, Lake Abitibi; 11, James Bay; 12, Lac la Ronge; 13, Keller Lake.

thompsonii[1] (Girard, 1852), were taken on the bottom at depths from 50–90 ft during June and July 1967. Two specimens of the spoonhead sculpin, *Cottus ricei* (Nelson, 1876), were also collected on the bottom from this lake, at 55 and 90 ft in June 1967. All nine specimens of *M. thompsonii* were females containing eggs less than 1 mm in diam. Perhaps the sexes are spatially isolated or the males guard egg masses during this period and thus do not enter nets. Temperatures in these depths range from 6.0 to 7.2 C during summer months. Heney Lake is at an altidude of 500 ft.

Four nets (1 inch and 1½ inch stretched mesh) set in the east part of Pemichangan Lake, Gatineau County (75°49′–75°54′ long, 46°01′–46°05′ lat, see Fig. 1), at a depth of 140 ft on August 1, 1967 captured 12 unusually large *C. ricei*. The largest specimen was 110.3 mm in standard and 134 mm in total length. McAllister and Lindsey (1960) list a maximum total length of 50 mm for this species. The largest specimen in the collection of the National

[1]This species is called *M. thompsonii* rather than *M. quadricornis* in accordance with McAllister (1961).

J. FISH. RES. BD. CANADA, 25(12): 2733–2737, 1968.
Printed in Canada.

Museum of Natural Sciences, Ottawa, Ont., previous to the present find was 76.6 mm standard length, from Thelon River, N.W.T.

Slight pressure on the abdomen of males of *C. ricei* at the time of capture caused milt to be extruded. This is unusual because the species has been considered (Scott, 1954) as a spring spawner. Temperature was 4.5 C at 140 ft during August. Lake Pemichangan is at an altitude of 550 ft.

Comparisons were made between these *C. ricei* and other populations from Heney Lake and Thelon River. No morphometric or meristic differences were noticed between Heney and Pemichangan specimens of *C. ricei* (Table I). However, the samples from the two areas average a higher total number of fin rays (anal + pectoral + dorsal) than samples from northwestern Canada. Anal ray counts, which tend to be clinal (McAllister, MS, 1957), agree with those of samples from the Great Lakes basin (13–16) rather than those of samples from the Northwest Territories (11–14).

Myoxocephalus thompsonii from Heney Lake does not differ noticeably from samples of four other populations examined (Table II).

Cottus ricei has previously been reported only once from Quebec; from the St. Lawrence River near Neuville, St. Nicholas, and Ste. Pétronille (Île d'Orléans) (Vladykov, 1949). This area is some 220 miles to the east of the Heney and Pemichangan areas and our record fills in a gap between the St. Lawrence records and those from Ontario in the Great Lakes, Lake Nipigon, and James Bay drainages. The western Quebec record for *C. ricei* reported by Scott (1967) is based on the Lake Abitibi capture of July 1925 by Dymond and Hart (1927). The point of capture was in Ontario but since Lake Abitibi extends into Quebec it was assumed that *C. ricei* occurs in both the Quebec and the Ontario portions of the watershed.

Myoxocephalus thompsonii has not previously been reported from Quebec. The closest record and the only other one from the Ottawa River drainage basin is from Cedar Lake, Algonquin Park, Ontario (Martin and Chapman, 1965), about 130 miles to the west of Heney Lake. The deepwater sculpin is otherwise known from the Great Lakes, Lake Nipigon, and lakes northwest of these in Manitoba, Saskatchewan, and the Northwest Territories (see map in McAllister, 1961). The isolated Heney Lake record, the most easterly for this species, is of zoogeographic interest. The proglacial lake theory, used by McAllister (1961) to explain dispersal elsewhere in North America, cannot be employed in the present instance. As the deepwater sculpin is found in Lake Ontario, it could have reached Heney Lake by passage down the St. Lawrence River and up the Ottawa and Gatineau rivers. A simpler hypothesis would be that the deepwater sculpin, as the glaciers retreated, dispersed downstream in the Fossmill outlet channel of the Algonquin stage of the Great Lakes. This outlet drained what is now Georgian Bay down the Petawawa River into the Ottawa River. Martin and Chapman (1965) used this theory to explain certain relicts in Cedar and neighbouring lakes. After dispersal in the Ottawa system and postglacial warming of the climate, distribution would be restricted to deep, cool lakes.

TABLE I. Morphometric and meristic data on specimens of *Cottus ricei* in the collection of the National Museum of Natural Sciences, Ottawa, Ont.

Locality and collection no.	Standard length (*mm*)	Body depth[a]	Head length[a]	Caudal peduncle depth[b]	Pectoral length[b]	Rays					L.L. pores
						Second dorsal[c]	Anal[c]	Anal $\bar{X}$	Pectoral	Total D_2+A+P	
Heney Lake, Que., NMC67-210(2)	70.4–73.3	.18	.29	.17–21	.8–.9	18–19	14–15	14.5	16	48–50	30–35
Heney Lake, Que., summer 1968 (27)	80.0–109.0	–	–	–	–	16–19	12–15	13.5	15–16	43–50	–
Pemichangan Lake, Que., NMC584-(12)	73.4–110.3	.17–.19	.28–.29	.15–.19	.8–.9	17–19	13–14	–	15–18	45–51	32–38
Thelon R., N.W.T., NMC64-476(7)	53.5–76.6	.15–.17	.30–.33	.13–.15	.7–.9	16–18	12	12	14–15	42–45	34–42

[a]As a fraction of the standard length.
[b]As a fraction of the head length.
[c]Last two rays of dorsal and anal fins counted as one.

TABLE II. Morphometric and meristic data on specimens of *Myoxocephalus thompsonii* in the National Museum of Natural Sciences, Ottawa, Ont.

Locality and collection no.	Standard length (*mm*)	Body depth[a]	Head length[a]	Caudal peduncle depth[b]	Extent of lateral line	Development of tubercles	Rays				
							First dorsal	Second dorsal[c]	Anal[c]	Anal $\bar{X}$	Pectoral
Heney Lake, Que., NMC67-295(9)	74.9–99.9	.15–.20	.28–.34	.13–.17	Not to end D2	Poor; few	7–8	12–14	10–14	12.5	15–17
Heney Lake, Que., summer 1968 (6)	85–98	–	–	–	–	–	6–8	13–14	12–14	13.3	15–17
Lake Huron, NMC60-493-A(3)	102.1–141.2	.20–.22	.32–.34	.15–.18	Past end of D2	Better	8	14–15	14–15	–	17
Lake Michigan, NMC64-719-(4)	87.6–119.7	.20–.21	.32–.34	.14–.16	Not to end D2	Poor; few	7–8	12–14	13–15	–	16–17
Lac la Ronge, Sask., NMC67-293(1)	79.2	.17	.34	.14	Past end of D2	Better	8	14	14	14	16
Keller L., N.W.T., NMC63-108(1)	64.8	.17	.34	.13	Past end of D2	Better	7	15	15	15	16

[a]As a fraction of the standard length.
[b]As a fraction of the head length.
[c]Last two rays of dorsal and anal fins counted separately.

In the summer of 1968, in studies on the ecology and behavior of both species in the Gatineau Valley area, the second author took numerous *C. ricei* and young-of-the-year *M. thompsonii* from Heney Lake. *Cottus ricei* specimens were as large as those from Lake Pemichangan.

As Martin and Chapman (1965) observed in Algonguin Park, Ontario, the relict crustaceans *Mysis relicta* and *Pontoporeia affinis* are also found in Pemichangan and Heney Lake in close relation to *M. thompsonii* and *C. ricei*.

The specimens of both species are deposited in the fish collection of the National Museum of Natural Sciences, Ottawa, Ont.; the catalog numbers are given in the tables.

We are especially grateful to Dr D. E. McAllister, Curator of Fishes, National Museum of Natural Sciences, for suggesting the note and for his comments on postglacial dispersal.

Biology Department
University of Ottawa, Ottawa, Ont.

CLAUDE DELISLE[2]
W. VAN VLIET[3]

Received for publication June 18, 1968.

REFERENCES

DYMOND, J. R., AND J. L. HART. 1927. The fishes of Lake Abitibi (Ontario) and adjacent waters. Univ. Toronto Studies, Biol. Ser., No. 29, Publ. Ont. Fish. Res. Lab., No. 28. p. 1–19.

MARTIN, N. V., AND L. J. CHAPMAN. 1965. Distribution of certain crustaceans and fishes in the region of Algonguin Park, Ontario. J. Fish. Res. Bd. Canada, **22**(4): 969–976.

MCALLISTER, D. E. MS, 1957. The systematics of the freshwater sculpins of British Columbia. M.A. Thesis. University of British Columbia, Vancouver, B.C. 109 p.
1961. The origin and status of the deepwater sculpin, *Myoxocephalus thompsonii*, a Nearctic glacial relict. Natl. Museum Canada, Bull. No. 172. p. 44–65.

MCALLISTER, D. E., AND C. C. LINDSEY. 1960. Systematics of the freshwater sculpins (*Cottus*) of British Columbia. Ibid., No. 172. p. 66–89.

SCOTT, W. B. 1954. Freshwater fishes of eastern Canada. 2nd ed., 1967. University of Toronto Press, Toronto, Ont. 137 p.

VLADYKOV, V. D. 1949. Les cottidés d'eau douce du Québec. Ann. Assoc. Canadienne-Française Advan. Sci., **15**: 85.

---

[2]Present address: Montreal Aquarium, Parks Department, La Ronde, Ile Ste-Hélène, Montreal, Quebec.

[3]Mr. Van Vliet tragically drowned while working at Heney Lake, Quebec, on October 20, 1968.

Surface Phosphate and Silicate Distributions in the Northeastern Pacific Ocean

During the oceanographic and geophysical cruise of USC and GSS *Surveyor*, April–May 1968, we continuously monitored the surface phosphate and silicate concentrations in the northeastern Pacific Ocean by means of a Technicon® Autoanalyzer.®

Sea water was continuously pumped into a chemistry laboratory aboard the Surveyor through a submerged intake in the bow of the ship. Detailed laboratory procedure is similar to that of Armstrong et al. (1967).

Surface phosphate distribution (Fig. 1) shows a close resemblance to the general circulation of northeastern Pacific Ocean. A surface maximum

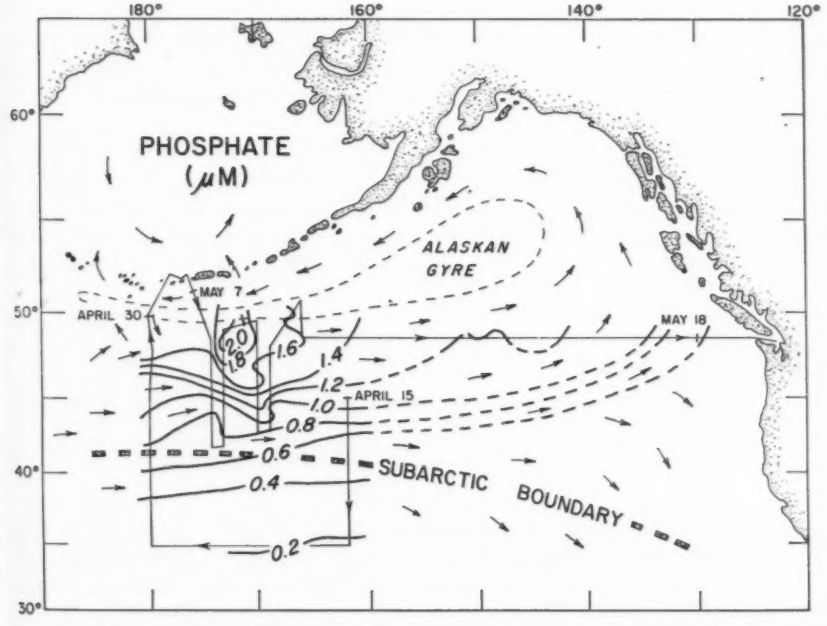


FIG. 1. Surface phosphate distribution of northeastern Pacific Ocean, April 15–May 18, 1968. Concentrations are in micromolars. The cruise track of USC and GSS *Surveyor* is shown by a solid line. The general circulation pattern, shown by arrows, was furnished by Percy Wickett of Fisheries Research Board of Canada, Biological Station, Nanaimo, B.C.

of over 2.0 μM was observable near 49°N, 173°W, between the Alaskan Stream and the subarctic current. In general, the northside of the subarctic boundary was high in phosphate content, over 0.6 μM. In the subtropic region, below

J. FISH. RES. BD. CANADA, **25**(12): 2739–2741, 1968.
Printed in Canada.

40°N, the phosphate concentration drops continously; at 35°N it was about 0.2 μM.

Silicate distribution (Fig. 2) shows the same trend we saw in the phosphate distribution (Fig. 1). It has a maximum of over 30 μM at 49°N, 173°W. The north side of the subarctic boundary has, in general, more than 10 μM of silicate whereas the south side has less than 10 μM.

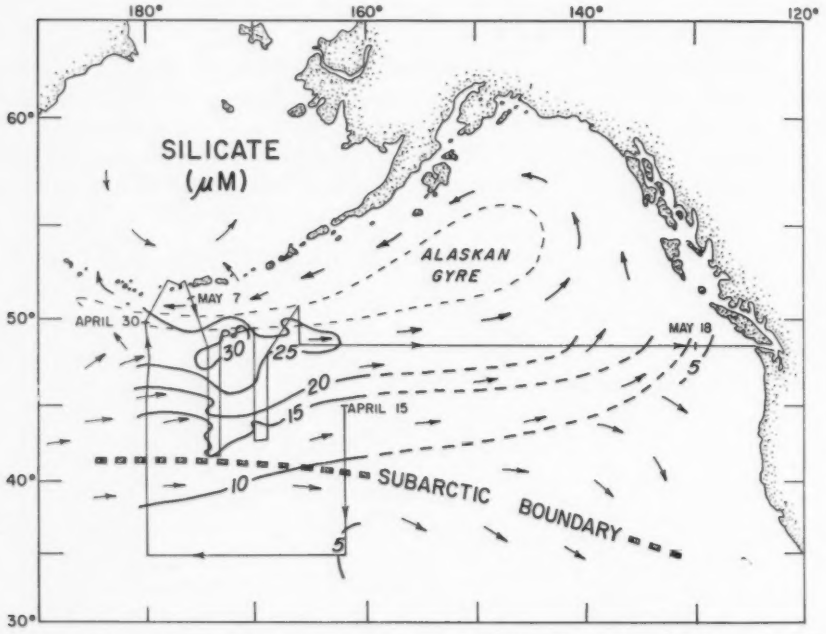


FIG. 2. Surface silicate distribution of northeastern Pacific Ocean, April 15–May 18, 1968. Concentrations are in micromolars. The cruise track of USC and GSS *Surveyor* is shown by a solid line. The general circulation pattern, shown by arrows, was furnished by Percy Wickett of Fisheries Research Board of Canada, Biological Station, Nanaimo, B.C.

Throughout the cruise we observed practically no plant pigment content; no chlorophyll *b* and *c*, plant carotenoid, and less than 0.2 mg chlorophyll *a*/m³ of sea water. However, the lack of the pigments in the standing stock of phytoplankton does not imply that the nutrient distributions we observed are before the spring phytoplankton bloom. Parsons et al. (1966) pointed out that the pigment concentration undergoes little seasonal change at the weather ship station P, owing to intensive zooplankton grazing which commences simultaneously with a net increase in the primary production.

The approximate timing of the spring phytoplankton bloom in the northeastern Pacific Ocean, shown by Parsons et al. (1966), indicates that the high nutrient area (Fig. 1 and 2) has a very late production in April–May. Therefore, it may account for the high nutrients we observed.

At the same time we cannot rule out the possibility that the occurrence of phosphate and silicate maxima near the Aleutian Trench may be a product of the upward divergence of the subsurface water. The maximum surface values of 2.1 μM for phosphate and 33 μM for silicate correspond to approximately 100 m concentrations that were observed in June 1966 (Park, 1967). Possible winter turn-over of water layers in the upper 100 m could cause it.

Felix Favorite of the Bureau of Commerical Fisheries in Seattle, Wash., suggested to us that the phosphate distribution (Fig. 1) may indicate that a significant amount of water in the Alaskan Stream was blocked from further westward flow near 172°W long and turned southward and eastward in the subarctic current at this longitude. His observation of a tongue of dilute water (approximagely 32.5% S) in this area would tend to confirm his suggestion.

Various biological and physical processes obviously interplay to present us with the nutrient data we observed. Further studies are needed to assess each process. For such a purpose we propose that continuous surface nutrient measurements be carried out, through numerous ship of opportunity programs, to gather data indicative of the important fertility index of the oceans. The Technicon Autoanalyzer® is suited for such endeavours, requiring a minimum of manpower and incorporating little operator error.

This work was supported by the U.S. National Science Foundation grant GA-1281, Office of Naval Research contract Nonr 1286 (10), and U.S. Bureau of Commercial Fisheries. We thank H. C. Curl, Jr., T. V. Ryan, and Captain H. Nygren for technical assistance, and T. R. Parsons and F. Favorite for their valuable criticisms of the manuscript.

Department of Oceanography
Oregon State University, Corvallis, Ore. 97331

P. Kilho Park
Stephen W. Hager
Jacques E. Pirson
David S. Ball

Received for publication August 23, 1968.

REFERENCES

Armstrong, F. A. J., C. R. Stearns, and J. D. H. Strickland. 1967. The measurement of upwelling and subsequent biological processes by means of the Technicon Autoanalyzer and associated equipment. Deep-Sea Res., **14**(3): 381–389.

Park, K. 1967. Chemical features of the subarctic boundary near 170°W. J. Fish. Res. Bd. Canada, **24**(5): 899–908.

Parsons, T. R., L. F. Giovando, and R. J. Lebrasseur. 1966. The advent of the spring bloom in the eastern subarctic Pacific Ocean. Ibid., **23**(4): 539–546.

Estimating Mean Weight from Length Statistics

Biologists frequently need to estimate weights (y) of fish from their lengths (x), and numerous weight–length relationships have been developed empirically for different species, populations, life-history stages, seasons, and so on. Most or all take the form:

$$y = c \cdot x^n \qquad \ldots\ldots(1)$$

where c is a constant and the exponent n commonly has values between 2.5 and 3.5, often being quite close to 3. From such relationships, weight can be estimated from length *for individual fish.*

Another common situation is where a quick estimate of the mean weight of the fish of a particular age-group of a species is desired — without going through the tedious computation of individual weights. For this purpose the weight corresponding to the observed mean length of the fish sampled has sometimes been used, but this estimate of course has a systematic bias that makes it too low (Ricker, 1958, p. 191). For any given mean length, this bias increases with the variability in length of the fish in the sample.

This note describes an unbiased and reasonably exact estimate of mean weight that can be obtained in any situation where the frequency distribution of lengths in a sample is approximately normal, where their mean and variance have been computed, and of course where a relationship of the type shown in equation 1 is available.

General theory. — Suppose x, the length of fish caught of a certain age-group in a species, is a normal random variable with mean μ and variance σ^2, i.e. x is $N(\mu, \sigma^2)$, so that its probability density is given by

$$\varphi(x) = (1/\sigma\sqrt{2\pi}) \exp\left[-(x-\mu)^2/2\sigma^2\right].$$

Then the expected value of a function of x, say $\psi(x)$, is given by

$$E[\psi(x)] = \int_{-\infty}^{\infty} \psi(x) \cdot \varphi(x)\, dx \qquad \ldots\ldots(2).$$

Suppose, further, that the weight, y, of a fish is given by

$$y = c \cdot x^n$$

$$\text{i.e. } y = \psi(x) = c \cdot x^n$$

where c and n are *known.*

J. Fish. Res. Bd. Canada, 25(12): 2743–2747, 1968.
Printed in Canada.

The problem is to express the mean weight of a group of fish (usually all one age) in terms of the parameters (mean and variance) of the normal distribution of their lengths. Using equation 1 the mean weight can be expressed as

$$E(y) = \int_{-\infty}^{\infty} c \cdot x^n \, \varphi(x) \, dx$$

$$= \int_{-\infty}^{\infty} (1/\sigma\sqrt{2\pi}) \cdot c \cdot x^n \exp\left[-(x-\mu)^2/2\sigma^2\right] dx \qquad \ldots\ldots(3).$$

Case I. — For the special case of so-called isometric growth, $n = 3$, and we obtain from equation 3:

$$E(y) = c/\sigma\sqrt{2\pi} \int_{-\infty}^{\infty} x^3 \exp\left[-(x-\mu)^2/2\sigma^2\right] dx$$

and by letting $t = (x-\mu)/\sigma$, we get

$$E(y) = c/\sigma\sqrt{2\pi} \int_{-\infty}^{\infty} (\sigma t + \mu)^3 \exp(-t^2/2) \cdot \sigma \cdot dt$$

$$= c/\sqrt{2\pi} \int_{-\infty}^{\infty} (\sigma^3 t^3 + 3\sigma^2 t^2 \mu + 3\sigma t \mu^2 + \mu^3) \exp(-t^2/2) \, dt$$

$$= c(\sigma^3 I_1 + 3\sigma^2 \mu I_2 + 3\sigma \mu^2 I_3 + \mu^3 I_4)$$

I_1 and I_3 are both zero, being respectively the first and third moments of a N(0, 1) variable, whereas I_2 is the second moment of a N(0, 1) variable and therefore equal to unity, and

$$I_4 = 1/\sqrt{2\pi} \int_{-\infty}^{\infty} \exp(-t^2/2) \, dt$$

is simply the total cumulative distribution function of the N(0, 1) variable which, by definition, equals unity. We get therefore:

$$E(y) = c \cdot (3\sigma^2\mu + \mu^3) = c \cdot E(x^3).$$

The difference between $E(y)$ and $c \cdot [E(x)]^3$, in terms of the parameters of the distribution of x, is therefore

$$c \cdot (3\sigma^2\mu + \mu^3) - c \cdot \mu^3 = 3c \cdot \sigma^2 \mu$$

or, in terms of the sample estimates

$$E(y) - c \cdot [E(x)]^3 = 3c \cdot s_x^2 \cdot \bar{x}.$$

The difference, as a fraction of the latter, i.e. of $c \cdot \bar{x}^3$, is $3 \cdot s_x^2/\bar{x}^2$.

In general, for integer values of n, it is easily shown that

$$E(y) = c \cdot \left[\mu^n + \frac{n!}{(n-2)!2!} \mu^{n-2}\sigma^2 + \frac{3n!}{(n-4)!4!} \mu^{n-4}\sigma^4 + \right.$$

$$\left. + \frac{5n!}{(n-6)!6!} \mu^{n-6}\sigma^6 + - - - - \right] \quad \ldots\ldots(3)$$

which we abbreviate to

$$E(y) = c. \left[\mu^n + a_1\mu^{n-2}\sigma^2 + a_2\mu^{n-4}\sigma^4 + a_3\mu^{n-6}\sigma^6 + - - - - \right] \quad \ldots\ldots(4)$$

where the number of terms is given by the integer part of $(n + 2)/2$. We get from equation 3 (omitting the multiplier c):

n	$E(y)$
1	μ
2	$\mu^2 + \mu^\circ\sigma^2$
3	$\mu^3 + 3\mu^1\sigma^2$
4	$\mu^4 + 6\mu^2\sigma^2 + 3\mu^\circ\sigma^4$
5	$\mu^5 + 10\mu^3\sigma^2 + 15\mu^1\sigma^4$
6	$\mu^6 + 15\mu^4\sigma^2 + 45\mu^2\sigma^4 + 5\mu^\circ 9^6$

If the parameters of the distribution of x are now replaced by the sample statistics, it is possible to express $E(y)$ in the appropriate number of terms of equation 4, and thus in terms of the distribution statistics of x.

As a simple illustration, assume x is N(100, 100) and $y = 0.5x^3$, with the sample values of x shown in Table I. We have:

Mean length	$= \bar{x} = 100$
Sample variance	$= s_x^2 = 133.33$
"True" mean weight (Table I)	$= \bar{y} = 518{,}252$
Estimated mean weight	$= c \cdot [E(y)] = 0.5[(100)^3 + 3 \times 100 \times 133.33]$
	$= 520{,}000$
Weight of a fish of mean length	$= c[E(x)]^3 = 0.5(100)^3$
	$= 500{,}000$

Thus the mean weight estimated from equation 4 is only 0.3% different from the mean weight of the sample, as computed for individual fish using equation 1. The weight of a fish of average length, however, is 3.8% less than the mean weight of the fish sampled.

TABLE I. Lengths of a sample of 16 fish from a normally distributed population, and the corresponding weights computed from $y = 0.5\,x^3$ and from $y = 0.5\,x^{3.3}$.

Length x	Weight $y = 0.5\,x^3$	Weight $y = 0.5\,x^{3.3}$
109	647,514	2,645,350
104	562,432	2,265,550
79	246,520	914,400
107	612,522	2,488,350
115	760,438	3,157,100
105	578,812	2,338,250
84	296,352	1,119,650
101	515,150	2,056,950
98	470,596	1,862,200
92	389,344	1,511,800
78	237,276	876,700
104	562,432	2,265,550
103	546,364	2,194,500
112	702,464	2,893,350
96	442,368	1,739,650
113	721,448	2,979,450
Sum 1600	8,292,032	33,308,800
Mean 100	518,252	2,081,800

Case II. — When n is not an integer, equation 4 may still be used in an appropriate form, the necessary a values being obtained by interpolation. Approximate values of a_1 and a_2 for noninteger $n \leq 5$ are given in Table II (obtained by nonlinear interpolation). In this case the number of terms to be used is the integral part of $(n + 3)/2$.

As an example, suppose that for the sample of 16 lengths in Table I, the weight–length relationship is:

$$y = 0.5x^{3.3}.$$

The corresponding computed weights are shown in column 3 of Table I.

From Table II, $a_1 = 3.77$ and $a_2 = 0.6$. Substituting these in equation 4 along with μ (taken as $\bar{x} = 100$) and σ^2 (taken as $s_x^2 = 133.33$), we obtain the following estimate of the mean weight of the fish in the sample:

$$\begin{aligned} c\cdot[\mathrm{E}(x^{3.3})] &= 0.5[(100)^{3.3} + 3.77 \times 100^{1.3} \times 133.33 + 0.6 \times 100^{-0.7} \times (133.33)^2] \\ &= 0.5[3{,}981{,}100 + 3.77 \times 398.11 \times 133.33 + 0.6 \times 0.39811 \times (133.33)^2] \\ &= 0.5[3{,}981{,}100 + 200{,}110 + 420] \\ &= 2{,}090{,}820. \end{aligned}$$

This is only 0.4% greater than the "true" mean weight of 2,081,800, as calculated for the individual fish using equation 1 (Table I).

TABLE II. Approximate values of the coefficients a_1 and a_2 of equation 4 in the text for values of n from 1.0 to 5.0.

n	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
						a_1					
1	0.00	0.08	0.15	0.23	0.32	0.42	0.52	0.63	0.74	0.87	1.00
2	1.00	1.14	1.31	1.48	1.66	1.86	2.07	2.29	2.52	2.75	3.00
3	3.00	3.25	3.51	3.77	4.04	4.32	4.62	4.95	5.29	5.64	6.00
4	6.00	6.36	6.73	7.11	7.50	7.90	8.31	8.72	9.14	9.57	10.00
						a_2					
3	0.00	0.2	0.4	0.6	0.9	1.2	1.5	1.8	2.2	2.6	3.0
4	3.00	3.5	4.1	4.9	5.9	7.1	8.4	9.7	11.3	13.0	15.0

The mean weight of a fish of average length in the sample is given by:

$$c[\mathrm{E}(x)]^{3\cdot3} = 0.5(100)^{3\cdot3} = 1{,}990{,}500.$$

This is 4.4% less than 2,081,800, so that again equation 4 gives a much better estimate of "true" mean weight.

Fisheries Research Board of Canada
Biological Station, Nanaimo, B.C.

L. V. PIENAAR
W. E. RICKER

Received for publication August 29, 1968.

REFERENCES

RICKER, W. E. 1958. Handbook of computations for biological statistics of fish populations. Bull. Fish. Res. Bd. Canada, No. 119.

Possible Effects of the Harbour Seal Bounty on Codworm Infestations of Atlantic Cod in the Gulf of St. Lawrence, the Strait of Belle Isle, and the Labrador Sea

Infestation of the Atlantic cod (*Gadus morhua* L.) with larvae of the nematode genera *Porrocaecum* and *Anisakis* occurs in the Labrador Sea and presents a problem of economic importance in some areas of the northern Gulf of St. Lawrence and off southwestern Newfoundland.

In the present study fillets of Atlantic cod 41 cm and over in length were examined for nematodes to compare recent (1966–67) infestations with those found by Templeman et al. (1957) for the years 1947–53.

The areas sampled (Fig. 1) were off western Newfoundland; off southwestern Newfoundland; off the north (Quebec) shore of the Gulf of St. Lawrence; the Labrador Sea from Cape Chidley in the north to central Hawke Channel in the south; and the Strait of Belle Isle. The first four areas correspond fairly well to areas 14 plus 19, 20, 15, and 8 plus 11, respectively, of table IV and fig. 11 in Templeman et al. (1957). The Strait of Belle Isle was not sampled in the earlier survey.

This paper assesses the effects on codworm infestations of Atlantic cod in the above areas of a government bounty on harbour seals (*Phoca vitulina* L.) introduced to Newfoundland and Labrador in October 1952.

Cod were caught in otter trawls by the Canadian research vessels *A. T. Cameron* and *Investigator II* in the fall of 1966 and spring and early summer of 1967 (Table I). Skinned fillets were candled over glass using a 150-w bulb, and the numbers of nematodes were determined by systematic destructive examination of the flesh. The majority of the specimens recorded were assumed to be larvae of *Porrocaecum decipiens* for several reasons: they resembled the descriptions of this species given by Scott (1954) and Scott and Black (1960); Templeman et al. (1957) reported that 84–100% of nematodes in Atlantic cod fillets from the northern Gulf of St. Lawrence and the Labrador Sea were *Porrocaecum*; and Scott (1956) showed that all larval *Porrocaecum* specimens from fillets of Atlantic cod in Canadian Atlantic waters are probably *P. decipiens*.

Since 1947–53, in the Labrador Sea and off the north shore of the Gulf of St. Lawrence the percentage of cod infested (incidence) and the number of worms per 100 cod (occurrence) have increased ($P < 0.05$) whereas the number of worms per infested fish (intensity) increased only in the latter area (Table I). For western Newfoundland, incidence and occurrence decreased appreciably although intensity rose ($P < 0.005$). In the southwestern Newfoundland–north St. Pierre Bank area, occurrence and intensity decreased markedly whereas incidence remained unchanged.

The Strait of Belle Isle was studied in the present survey because it was not sampled by Templeman et al. (1957) and because it is uncertain (Templeman, 1962) whether Atlantic cod in the Strait are of the Labrador–northeast

J. Fish. Res. Bd. Canada, 25(12): 2749–2753, 1968.
Printed in Canada.

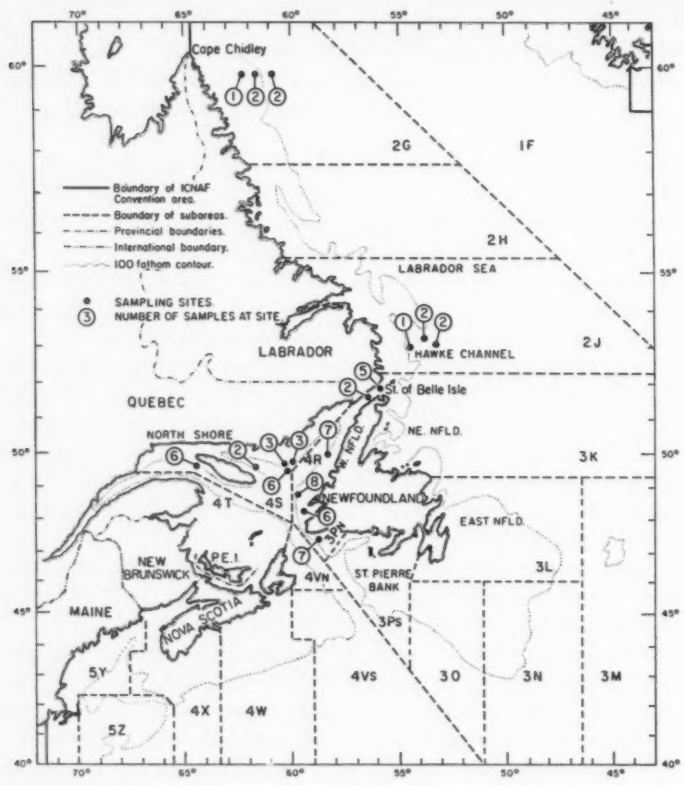


FIG. 1. Areas sampled from the Gulf of St. Lawrence to the Labrador Sea for nematode larvae in fillets of Atlantic cod 41 cm and over in length.

Newfoundland stock or the western Newfoundland stock. Observed infestations in the strait of Belle Isle were low and resembled the data from the Labrador Sea (Table I). This suggests that the fish caught in the Strait of Belle Isle belonged to the Labrador–northeast Newfoundland stock.

The effect of harbour seal bounty kills on the nematodes in the northeastern Gulf and Labrador marine areas was probably small. This conclusion is based on the following evidence: bounty records for harbour seals from the Newfoundland and Labrador region (Department of Fisheries of Canada, St. John's, Nfld.) show that reported kills have steadily declined from an average of 1000–2000 annually during 1952–55 to around 1000 in 1961–64 and 800 in 1965–66; about 70% of the kills were in Labrador during 1952–55 and over 90% in recent years; and about 85% of the kills since 1952 were of pups less than 1 year old. Labrador is an area of low codworm infestation (Table I) and harbour seal pups are not as heavily infested as older animals (Scott and

TABLE I. Infestations of fillets of Atlantic cod from various areas by nematode larvae in 1947–53 (Templeman et al., 1957) and 1966–67. Significant values of P are underlined.

Area	No. of cod examined		% of cod infested			No. of worms per 100 cod			No. of worms per infested cod		
	1947–53	1966–67	1947–53	1966–67	P[a]	1947–53	1966–67	P[a]	1947–53	1966–67	P[a]
Strait of Belle Isle (ICNAF 4R)	–	327	–	2.9±0.6[b]	–	–	8.7±4.5	–	–	2.80±1.00	–
Labrador Sea (ICNAF 2 GJ)	1731	312	3.7±1.9	4.2±2.6	<.005	4.3±1.8	5.6±2.2	<.001	1.13±0.56	1.23±0.77	>.1
North shore Gulf of St. Lawrence (ICNAF 4S)	259	508	21.7±13.3	26.2±11.7	<.005	33.3±24.5	52.4±38.1	<.05	1.36±0.32	1.84±0.80	<.001
Western Newfoundland (ICNAF 4R)	1228	623	34.7±8.5	20.7±5.6	<.001	73.3±29.8	60.3±27.0	<.005	2.06±0.52	2.76±0.58	<.005
SW Newfoundland & north St. Pierre Bank (ICNAF 3PN)	935	148	29.7±3.3	30.7±9.0	>.1	109.3±13.2	66.4±35.6	<.001	3.78±0.20	2.04±0.72	<.001

[a]Significance of difference between averages determined by Student's t-test.
[b]Standard deviation of mean.

Fisher, 1958), so that bounty kills will remove only a small proportion of the adult nematode population from the sea. The recent rise in infestations in the northern areas, from where most bounty kills were reported, supports this conclusion.

The following considerations also raise the question of the effectiveness of the harbour seal bounty. There is no bounty on the other seal species (the harp seal, *Phoca groenlandica* (Erxleben), and the grey seal, *Halichoerus grypus* (Fabricius)), which occur over most of the Labrador Sea and the Gulf of St. Lawrence (Mansfield, 1967). These are known vectors of *Porrocaecum decipiens* and deposit nematode eggs into the sea with their faeces (Scott, 1950; Fisheries Research Board of Canada, Annual Report, 1951, p. 29–31). The role of three seal species as vectors was estimated by Mansfield (1968) from a consideration of *P. decipiens* infestations in samples of seals from the Gulf of St. Lawrence during 1966–67. Adjusting for the restricted stay (4 months of the year) of harp seals within the Gulf of St. Lawrence, he concluded that the relative importance of harbour, grey, and harp seals as vectors of *P. decipiens* in the area is 2, 45, and 53% respectively. Thus, the harbour seal is apparently the least important vector in the Gulf of St. Lawrence and probably also in the Labrador Sea.

Dr D. E. Sergeant (Fisheries Research Board of Canada, Ste. Anne de Bellevue, Que., personal communication) suggested that the rise in *P. decipiens* off the north shore of the Gulf of St. Lawrence might be due to an increase he has observed in a local breeding population of harp seals in the northern Gulf of St. Lawrence. He noted, however, that an increase in western Newfoundland infestations might be expected if these harp seals caused the rise off the north shore. The present author suggests that the western Newfoundland sampling sites (Fig. 1) were too far south to be influenced by a northern local breeding population of harp seals and that this may explain the nonincrease in *P. decipiens* infestations off western Newfoundland. The apparent decline in western Newfoundland infestations remains unexplained.

The foregoing conclusions on the effectiveness of harbour seal control must remain speculative since hunting has not been intense in the areas studied in this paper. A more meaningful idea of the effects hunting may have on *P. decipiens* infestations might emerge from extended studies of infestations of Atlantic cod in eastern Newfoundland waters, an area where harbour seal populations have been seriously reduced by bounty hunters (Dr D. E. Sergeant, Fisheries Research Board of Canada, Ste. Anne de Bellevue, Que., personal communication). Such findings may not apply to the areas covered in this study but would provide data derived from severely depleted seal populations which might serve as guidelines in assessing other areas.

Fisheries Research Board of Canada
Biological Station, St. John's, Nfld.

MICHAEL WILES[1]

Received for publication June 28, 1968.

[1]Present address: Department of Biology, Saint Mary's University, Halifax, N.S.

REFERENCES

FISHERIES RESEARCH BOARD OF CANADA. 1952. Ann. Rept. Atlantic Biol. Sta., 1951. p. 29–32.

MANSFIELD, A. W. 1967. Seals of arctic and eastern Canada. Bull. Fish. Res. Bd. Canada, No. 137. 35 p.

1968. Further studies of seals as vectors of codworm *Porrocaecum decipiens* in the Maritime Provinces. Fish. Res. Bd. Canada, Ann. Rept. Arctic Biol. Sta., 1967–68.

SCOTT, D. M. 1950. A preliminary report on the codworm investigation. Fish. Res. Bd. Canada, Atlantic Prog. Rept. No. 48. p. 10–12.

1954. Experimental infection of Atlantic cod with a larval marine nematode from smelt. J. Fish. Res. Bd. Canada, **11**(6): 894–900.

1956. On the specific identity of the larval *Porrocaecum* (Nematoda) in Atlantic cod. Ibid., **13**(3): 343–356.

SCOTT, D. M., AND W. F. BLACK. 1960. Studies on the life-history of the ascarid *Porrocaecum decipiens* in the Bras d'Or Lakes, Nova Scotia, Canada. Ibid., **17**(6): 763–774.

SCOTT, D. M., AND M. D. FISHER. 1958. Indicence of the ascarid *Porrocaecum decipiens* in the stomachs of three species of seals along the southern Canadian Atlantic mainland. Ibid., **15**(4): 495–516.

TEMPLEMAN, W. 1962. Divisions of cod stocks in the northwest Atlantic. Intern. Comm. Northwest Atlantic Fish., Redbook, Part III. p. 79–123.

TEMPLEMAN, W., H. J. SQUIRES, AND A. M. FLEMING. 1957. Nematodes in the fillets of cod and other fishes in Newfoundland and neighbouring areas. J. Fish. Res. Bd. Canada, **14**(6): 831–897.

INDEX TO PUBLICATIONS FOR 1968[1]

In 1968 the Fisheries Research Board of Canada published Bulletin 164 containing a list of all articles, in all series, of publications and Studies that appeared up to the end of 1964, together with a subject–author index to all series. From 1965, a subject–author index and list of all Board publications (including Studies, Interpretive Articles, and Miscellaneous Special Publications) have been included in the last issue of each Journal volume. These follow the pattern and style used in Bulletin 164.

The present subject–author index is based on: (*a*) the 12 issues of Volume 25 of the Journal; (*b*) Bulletins 162–167 issued during 1968; Bulletin 131 which was published in French; and Bulletin 119 which was reprinted without revision. These titles are listed in the Lists of Publications for 1968 that follows this present index. (*c*) Circular series and Technical Reports from the Board's establishments issued during 1968 in time to be included; (*d*) "Miscellaneous Special Publications" includes special bindings and pamphlets which do not belong to a particular series of FRB publications; (*e*) Studies No. 1192–1262 (reprints of articles published in other periodicals, bound annually in two parts); (*f*) general reference to the 1967 Annual Report and the 1965/1966 Review; (*g*) Interpretive Articles 76–116 which appeared in non-Board publications, but which did not get included in the bound Studies (item *e* above).

The designation "(F)" in the index indicates the article referred to was published in French. Lists of titles of the individual publications and articles immediately follow this index, arranged under the following types of publications. (The list of articles in this Volume 25 of the Journal is in the form of a table of contents of its 12 issues, suitable for binding with this volume.)

Abbreviations used in the index for types of publications:

J — Journal of the Fisheries Research Board of Canada
B — Bulletin of the Fisheries Research Board of Canada
AR — Annual Report of the Fisheries Research Board of Canada
R — Review of the Fisheries Research Board of Canada (biennial)

Circulars of the Fisheries Research Board of Canada

CDG — Marine Ecology Laboratory, Bedford Institute, Dartmouth, N.S.
CHN — Halifax Laboratory, Halifax, N.S.
CJG — Biological Station, St. John's, Nfld.
CNG — Biological Station, Nanaimo, B.C. (General series)

[1]Subject index prepared by Neal M. Carter.

J. Fish. Res. Bd. Canada, 25(12): 2755–2849, 1968.
Printed in Canada.

CNS — Biological Station, Nanaimo, B.C. (Statistical series)
CSG — Biological Station, St. Andrews, N.B.
CVG — Vancouver Laboratory, Vancouver, B.C.

Miscellaneous

T — Technical Reports of the Fisheries Research Board of Canada
MSP — Miscellaneous Special Publications

Articles by FRB Staff published in non-Board publications

S — Studies of the Fisheries Research Board of Canada
A — Interpretive Articles of the Fisheries Research Board of Canada

Other abbreviations:

The Provinces and Territories of Canada are abbreviated to:

Alta. (Alberta)	N.W.T. (Northwest Territories)
B.C. (British Columbia)	Ont. (Ontario)
Man. (Manitoba)	P.E.I. (Prince Edward Island)
N.B. (New Brunswick)	Que. (Quebec)
Nfld. (Newfoundland)	Sask. (Saskatchewan)
N.S. (Nova Scotia)	Yuk. (Yukon)

Certain geographical areas (particularly oceans) have their major subdivisions designated by N (north), S (south), E (east), W (west), NE (northeast), etc., also Atl. (Atlantic), Pac. (Pacific).

Certain international commissions are commonly referred to as:
ICNAF (International Commission for the Northwest Atlantic Fisheries)
INPFC (International North Pacific Fisheries Commission)

In the index references, "re" is frequently used to imply "in relation to," "in connection with," and similar meanings; "vs." to imply such meaning as "in contrast to," "as opposed to."

A

Abnormality
J 25(11): 2503 (of Atl. herring otolith growth)

Absorption coefficient
J 25(3): 523 (of chlorophyll derivatives)

Abudefduf saxatilis (*see* Convict fish)

Abundance (*see also* Stocks)
J 25(1): 157 (*Mesidotea entomon* in Chignik Lakes Alaska)
(7): 1377 (changes in Lake Superior lake trout)
T 58 (of Nfld. herring re stocks & catches)
S 1255 (NW Atl. capelin)
A 105 (decline of herring, in B.C.)

Aburatsubo Inlet, Japan
J 25(4): 625 (production & mineralization of organic matter)

Acanthocephala
T 48 (parasitic to lampreys)

Acclimation; Adaptation
J 25(8): 1689 (re respiratory quotient determinations on fishes)
(12): 2717 (upper lethal temperatures at various salinities for mummichog & banded killifish after)
S 1259 (re NW Atl. decapod crustaceans)

Acetate
S 1236 (metabolism by Atl. salmon sperm)

Acetylcholine (*see* Choline)

Achromobacter cholinophagum
S 1229 (enzymic oxidation of betaine by)

Acids, amino (*see also* Protein; Proteolysis)
J 25(5): 935 (changes in free, of gillnetted Atl. cod skeletel muscle)
(6): 1247 (re transaminases distribution & activity in Pac. salmons tissues)
B 167: 81, 131 (determination in sea water)
S 1198 (re *Hemiselmis virescens* photo-trophic growth)
1237 (re metabolism by Atl. cod sperm)
1253 (re structure of plant viruses)
A 85 (of freshwater fishmeals)

Acids, fatty (*see also* Lipids; Oils and fats)
J 25(4): 733 (of trap-caught Atl. cod fillets after freezing)
(5): 921 (free: re nonbacterial trimethylamine formation in frozen Atl. cod & scallop muscle)
(5): 1061 (composition of redfish liver oil & Atl. "flounder liver oil")
(8): 1555 (free: starvation effect on rainbow trout blood plasma & muscle tissue)
(8): 1603 (of marine phytoplankters re taxonomy, etc.)
(10): 2059 (re protein extractability in iced Atl. cod muscle)
(10): 2083 (distribution in Atl. cod flesh lipids)
(11): 2419 (of seals depot fat & milk lipids, also commercial seal oil)
S 1192 (GLC resolution of Atl. herring oil & other monoethylenic)
1193 (phytanic & pristanic acid diastereomers from various fats as determined by GLC)
1203 (positional distribution of monoenoic, in animal glycerolipids)
1225 (chain-length overlap problem in GLC)
1226 (positional distribution in aquatic animals depot fat)
1227 (composition of fin whale milk lipids)
1228 (isoprenoid, phytanic, & pristanic acids of fish, whale, & seal oils, re feed)
1233 (incorporation of marine into mink & rat fatty tissues)
1238 (retention-times prediction in GLC of diastereoisomeric)
1250 (pancreatic enzyme substrate specificity re oleates)
1254 (stereoisomerism of present vs. geologically ancient shale isoprenoid)

Acids, nucleic (*see* Nucleosides)

Acids, polyfunctional metabolic (*see also* Acids, amino; Acids, fatty)
S 1222 (flame ionization detector molar responses for methyl esters of)

Acipenser fulvescens (*see* Sturgeon, lake)

Acipenser medirostris (*see* Sturgeon, green)

Acipenser sturio (*see* Sturgeon (European))

Acipenser transmontanus (*see* Sturgeon, white)

Ackman, Robert George
J 25(2): 267 (filter-feeding organism DMPT retention)
(4): 805 (FPC isopropyl alcohol retention)
(5): 1061 (redfish & flatfish oils re fatty acid composition)
(8): 1561 (jellyfish fatty acids)
(8): 1603 (phytoplankter fatty acids)
(10): 2083 (cod flesh lipid fatty acids)

S 1192 (gas chromatography of fatty acids)
1193 (diastereomers of phytanic & pristanic acids)
1203 (isomer distribution of monoenoic fatty acids)
1222 (flame ionization detector molar responses)
1225 (chain-length overlap problem)
1227 (fin whale lipids — fin whale milk)
1228 (isoprenoid fatty acids re whale oils)
1238 (GLC retention times of methyl-branched fatty acids diastereoisomers)
1254 (stereoisomerism in fatty acids)
A 101 (letter to the Editor — J. Gas Chromatog.)

Acoustics (*see* Sound; Sounding, echo)

Activity; Exercise; Fatigue (*see also* Stress; Swimming)
J 25(3): 603 (disturbance of rainbow trout: effects on blood)
(5): 837 (effects on glycogen & lactic acid in Atl. cod muscle & blood)
(6): 1285 (effect of light on brown trout)
(12): 2603 (swimming: effect on goldeye respiration)
B 162 : 80 fatigue in spawning migratory sockeye salmon)

Activity, coefficient of
S 1234 (of H_2O–NaCl–Na_2SO_4 system, re sea water)
A 108 : 17 (of NaCl & $MgSO_4$ ions in sea water)

Adaptation (*see* Acclimation)

Addison, Richard Frederick
J 25(10): 2083 (cod flesh lipid fatty acids)
S 1222 (flame ionization detector molar responses)

Adenosine
B 167 : 245 (determination of triphosphate in sea water)

Adrenal gland (*see also* Hormones)
J 25(2): 431 (sterone biosynthesis by herring)
(7): 1465 (metopirone effect on salmon and trout pituitary–interrenal function)
(12): 2549 (interrenalectomy & stress re blood components)
S 1244 (corticosteroid 1α-hydroxylase in elasmobranch)

Adrenaline and derivatives
J 25(3): 603 (disturbance effects on concention in rainbow trout)

Aequipecten irradians sablensis (*see* Scallop, bay)

Aeromonas species (*see also* Furunculosis)
J 25(7): 1521 (Great Lakes lampreys infection by)

Africa
J 25(12): 2527 (brown trout distribution)

Agassiz, Lake
A 100 (possible role in Man. fishes distribution)

Age; Age-groups (*see also* Age determination; Growth)
J 25(1): 157 (*Mesidotea entomon* in Chignik Lakes, Alaska)
(4): 657 (& growth of Ungava round whitefish)
(7): 1511 (& growth of Saskatchewan R. delta lake sturgeon)
(9): 1831 (F) (& growth of 4 Que. lakes maskinonge)
(9): 1993 (another 3rd-year pink salmon)
(12): 2589 (of Fraser R. white sturgeon)
B 165 : 12 (carp)
CNS 26 (B.C. chum salmon catches, 1957–63)
T 10 (composition of 1965 & 1966 sockeye salmon spawning run on escapement to Lakelse Lake, B.C.)
31 (Atl. mackerel)
57 (& length distribution, Bay of Fundy herring)
74 (sablefish)
S 1206 (of salmon from Labrador Sea & off W Greenland)
1255 (NW Atl. capelin)
A 99 (& size composition of Atl. cod)
108 (1966 Canadian ICNAF studies on age, age-groups, year-classes, etc. of various Atl. fishes)

Age determination (*see* Fins; Marking; Otoliths; Scales, fish; Tagging; Teeth)

Aggression (*see* Behaviour)

Agonopsis emmelane (*see* Poacher, northern spearnose)

Aholehole, Hawaiian (*Kuhlia scandricensis*)
J 25(8): 1651 (plasma protein-bound inorganic iodide)

Alaska; Gulf of Alaska
J 25(1): 157 (*Mesidotea entomon* biology in Chignik Lakes)
(3): 485 (spawning sockeye salmon behaviour Iliamna Lake)
(6): 1219 (Bristol Bay sockeye salmon oceanic mortality estimation)
(12): 2575 (physics & chemistry of 58 lakes & rivers)
T 18 (shrimp explorations, 1957–63)

Albacore (*Thunnus alalunga*)
S 1204 (population units study by serum transferrin polymorphism)
A 90, 103 (fishery trend along N America Pac. coast)

Albinism
J 25(7): 1323 (muscle enzyme comparison of normal vs. albino brook trout)

Alcohol
J 25(4): 805 (isopropyl: extraction solvent retention by fish protein concentrate)

Alderdice, Donald Francis
J 25(3): 495 (salinity & temperature effects on English sole)
(3): 585 (fish egg incubator)
A 87 (water pollution detection & measurement — biological assays)
T 41 (petrale sole embryonic development)
45 (extended tables of the transformation $\varphi = 2 \arcsin \sqrt{\bar{X}}$)

Alepocephalus convexifrons (a smoothhead)
J 25(12): 2665 (associations with other Oregon coast fishes)

Alewife (*Alosa pseudoharengus*)
J 25(1): 169 (pesticide residues in meals & oils)
(4): 667 (re Great Lakes species succession & exploitation)
A 85 (nutrient composition of meal as poultry feed)

Algae (*see also* names of classes; *also* Phytoplankton)
J 25(6): 1269 (benthic, as starch source in marine waters)
(8): 1603 (fatty acids of 8 classes of marine phytoplanktonic)
(10): 2037 (growth re primary production in a thermal stream)
(10): 2101 (re N utilization in subarctic lake)
S 1194 (antibacterial products of a marine planktonic alga)
1197 (aldolase activity in marine planktonic)
1248 (characterization of phospholipase C from *Monochrysis lutheri*)

Ali, Mohamed Ather
J 25(9): 2001 (F) (eye structure and habitat of yellow walleye & sauger)

Allen, Kenneth Radway
J 25(12): 2701 (computing recruitment rates)
T 20 : (St. Andrews biological station computer programs)
29 : (Maritime area Atl. salmon catches, 1949–65)
S 1217 (salmon growth rate)
1218 (Maritime Provinces Atl. salmon tagging results)
1235 (estimating effect on catch of size limit changes)

Allen, Richard Lee
J 25(11): 2467 (chinook mortality re *Dermocystidium*)

Almeida, Leslie Joseph
J 25(1): 197 (tropical fish disease microorganisms)

Alosa pseudoharengus (*see* Alewife)

Alosa sapidissima (*see* Shad, American)

Aluminum compounds
A 85 (in freshwater fishmeals)

Ambloplites rupestris (*see* Bass, rock)

America, North, Central, and South
J 25(12): 2527 (brown trout distribution)

Amia calva (*see* Bowfin)

Aminotransferases (*see* Enzymes)

Ammocoete (*see* Lamprey)

Ammodytes dubius (*see* Sand lance, northern)

Ammodytes hexapterus (*see* Sand lance, Pacific)

Ammonia
J 25(10): 2101 (utilization in subarctic lake)
B 167 : 87, 131 (determination in sea water)

Amoebaphyra ceratii (endoparasitic dinoflagellate)
J 25(10): 2241 (parasitic on *Gonyaulax catenella* dinoflagellate)

Amphibia (*see* Frog; Mudpuppy)

Amphineura (*see also* subclassifications)
T 2 (distributional checklist & bibliography of B.C. marine)
25, 35, 59, 60, 73 (in Strait of Georgia benthos biomass)

Amphipoda
J 25(5): 943 (*Anonyx* species of Atl. & Arctic coasts of N America)
(8): 1637 (habitat of 9 pelagic species in NE Greenland slope waters)
(9): 1803 (caloric content)
(11): 2461 (distribution of natural ^{65}Zn in *Anonyx* tissues)
(11): 2515 (caloric content of *Hyalella azteca*)
CNG 84 (popular description of some NE Pac. Ocean)

T 25, 35, 59, 60, 73 (in Strait of Georgia benthos biomass)
43 (on Irish moss)
47 (collections of *Anonyx* species from N American Atl. & arctic coasts)
55 : 103 (identification of B.C.)

Analysis, discriminant
T 40 (computer program for)

Analysis methods (chemical) *see also* Apparatus; Chromatography; Composition, chemical; Electrophoresis; etc.)
J 25(1): 71 (fluorimetry for salmonid plasma cortisol)
(8): 1525 (quantitative glycogen & Δ7P extraction from frozen muscle)
(11): 2505 (self-absorption of ^{14}C in samples)
B 167 (practical handbook of seawater analysis)
T 67 (volumetric, of noncomplexed ethylenediaminetetraacetic acid (EDTA) salts residues in fish-dipping solutions)
68 (colorimetric, of noncomplexed & complexed EDTA residues)
S 1249 (goldfish spermiation as bioassay for salmon gonadotropin)
1251 (recovery of microquantities of steroids after thin-layer chromatography)
A 81, 87 (for water pollutants)
101 ("Carbowax" types for gas–liquid chromatography)

Analysis methods (mathematical) (*see* Mathematical treatment)

Anarhichas lupus (*see* Wolffish, Atlantic)

Anarrhichthys ocellatus (*see* Wolf-eel)

Anatomy (*see* Morphology)

Anchovy (a tropical) (*see Coila dussumieri*)

Anchovy, northern (*Engraulis mordax mordax*)
T 22 (in B.C. experimental trawling)
A 90, 103 (increasing abundance off N America Pac. coast)

Anctil, Michel
J 25(9): 2001 (F) (eye structure and habitat of yellow walleye and sauger)

Anderson, John Murray
J 25(12): 2677 (sublethal DDT on brook trout lateral line)

Anderson, Margaret Lillian
J 25(10): 2059 (protein extractability & free fatty acid in cod)

Anesthesia; Anesthetic
J 25(1): 25 (M.S. 222 excretion in rainbow trout urine)

Angelfish (*Pterophyllum eimekei*)
J 25(8): 1739 (spinal ganglia position re taxonomy)

Anglemouth, veiled (*Cyclothone pacifica*)
T 11 (in B.C. experimental midwater trawling)

Anglerfishes (*see* Dreamers)

Angling (*see also* names of sport fishes, e.g. Trout; Salmon)
J 25(2): 209 (detailed data re stream ponding effect on brook trout)
(6): 1145 (harvest re mortality of maskinonge in 2 Ont. lakes)
(10): 2011 (fertilizing lake to increase trout growth & yield)

Anguilla (species)
T 28 (bibliography)

Anguilla anguilla (*see* Eel, European)

Anguilla japonica (*see* Eel, Japanese)

Anguilla rostrata (*see* Eel, American)

Animal food (*see* Feedstuff)

Anisakis (parasitic nematodes)
S 1206 (in Atl. salmon river)

Annelida
J 25(9): 1803 (caloric content of several species)
CNG 84 (popular description of some NE Pac. Ocean)

Anodonta californiensis (*see* Mussel, freshwater)

Anomalocera patersoni (a copepod)
A 108 : 17 (1966 Canadian ICNAF study on habitat)

Anonyx species (Amphipoda)
J 25(5): 943 (of Atl. & arctic coasts of N America)
(11): 2461 (distribution of natural ^{65}Zn in tissues)
T 47 (collections from Atl. & arctic coast of N America)

Anoplarchus insignis (a prickleback)
T 59 (in Strait of Georgia)

Anoplopoma fimbria (*see* Sablefish)

Anotopterus pharao (*see* Daggertooth)

Anoxia
J 25(1): 15 (re blood lactic acidosis of channel catfish in anoxia)

Anthozoa
T 25, 35, 59, 60, 73 (in Strait of Georgia benthos biomass)
43 (on Irish moss)

Antia, Navel Jamshedji
S 1194 (two *Isochrysis galbana* antibacterial products)
1197 (aldolase activity comparative studies)
1198 (growth of *Hemiselmis virescens*)
1248 (algal phospholipase C, properties)

Antibiotics, tetracycline
J 25(8): 1753 (CTC as bactericide & bacteriostat)

Antifouling treatments for vessels (*see* Boats)

Antimora rostrata (Pacific) (*see* Cod, longfin)

Antioxidants
J 25(4): 639 (α-tocopherol re metal-induced marine flesh oxidative rancidity)
CVG 40 (for spontaneous heating control in bulk herring meals)
A 80 (general summary re effect on nutritive value)

Aphanizomenon flos-aquae (*see also* Phytoplankton
J 25(6): 1229 (in phytoplankton ecology of an Ont. reservoir)

Aplodinotus grunniens (*see* Sheepshead)

Apodichthys flavidus (*see* Gunnel, penpoint)

Apostle Islands region (Lake Superior, Wisc.)
J 25(7): 1377 (lake trout rehabilitation)

Apparatus (*see also* names of types of fishing gear)
J 25(1): 26 (fish urine collection)
(1): 49 (fish swimming speed)
(1): 112 (hatching of sucker hybrids)
(1): 177 (harpoon adapter for tagging surface-swimming fish)
(2): 393 (effect of light on schooling & feeding of fish)
(3): 579 measuring fish growth re dissolved O_2 levels)
(3): 585 (incubator for small marine fish eggs)
(5): 837 (swimming stress effects on Atl. cod blood & muscle)
(6): 1115 (inducing sounding response in salmon)
(6): 1155 (Atl. cod auditory thresholds)
(6): 1161 (tidewater Atl. herring larvae sampling nets)
(6): 1285 (effect of light on brown trout activity)
(7): 1441 (fish attraction with pulsed low-frequency sound)
(7): 1453 (stream aquarium)
(7): 1485 (swimbladder volume determination)
(8): 1591 (testing rheotaxis of American eel)
(8): 1741 (water core plankton sampler)
(9): 1987 (red & white muscle temperature of recently caught fishes)
(10): 2040 (thermal stream water characteristics)
(10): 2123 (re underwater observation of scallop behaviour)
(11): 2453 (determining volatile sulphur compounds in soft-shell clams)
(11): 2519 (marking fish by high-frequency electric sparks)
B 162 : 164, 219, 220 (tow & plankton nets)
163 (instrumentation for engineering study of otter trawls)
166 (eel pots, nets, traps, weirs, spears, etc.)
CHN 34 (shrimp peeler)
CVG 38 (salmon-canning waste-water clarification)
39 (fishmeal pilot plant for research)
40 (adding antioxidants to bulk herring meals)
T 13 (types of B.C. trawling gear)
15 (fork vs. hydraulic rake for digging B.C. clams)
17 (micromagnetic tags for pink salmon fry)
38 (estuarine net counting fence for trapping Atl. salmon)
44 (lobster transplant shipment)
61 (exploratory shrimp trawling)
69 (mechanical unloading of fish from fishing vessel)
78 (octagonal pound for holding live fish)
85 (free-floating current followers)
MSP 10 (fish-scale reader; swimming speed respirometer)
S 1257 (estuarine net counting fence for trapping Atl. salmon)
1262 (electrofishing for coho salmon underyearlings)
A 112 (same as CVG 39 above)
116 (fish respirometer for salmon metabolism studies)

Applegate, Richard Lee
J 25(8): 1741 (water core plankton sampler)

Apristurus brunneus (*see* Shark, brown cat)

Aprodon cortezianus (*see* Eelpout, bigfin)

Aptocyclus ventricosus (*see* Lumpsucker, smooth)

Aquarium
J 25(1): 1 (behaviour of hatchery vs. wild Atl. salmon parr in)

Aquiferous system
J 25(3): 541 (for podium expansion in *Polinices*)

Arctic, Canadian (*see also* Oceanography, arctic)
J 25(2): 347 (hippolytid & crangonid shrimps — Queen Elizabeth Is.)
(5): 943 (*Anonyx* species off coasts)
(7): 1501 (F) (range extensions of lake trout in marine or saline regions of eastern)
(11): 2269 (description & distribution of 93 Bryozoa species)
(12): 2575 (physics & chemistry of some fresh waters)
T 47 (collections of *Anonyx* amphipods)

Arctica islandica (*see* Quahaug, ocean)

Argentine, Atlantic (*Argentinia silus*)
A 108 (1966 Canadian ICNAF studies: experimental catches; ages; etc.)

Argentines (general) (*see also* Barreleye; Blacksmelt; Smoothtongue)
T 11 (in B.C. experimental midwater trawling: *Nansenia candida*)

Argentinia silus (*see* Argentine, Atlantic)

Argis dentata (a crangonid shrimp)
J 25(2): 347 (Queen Elizabeth Is., Canadian arctic)
(9): 1803 (caloric content)

Aristostomias scintillans (*see* Loosejaw, Pacific)

Aro, Kosta Victor
S 1230 (spawning populations of N Pac. salmon)

Arrow-worm
CNG 84 (popular description of *Sagitta elegans*)

Arthropoda (*see also* classifications and common names)
J 25(9): 1803 (caloric content of several species)

Arurkar, Suresh Krishnaji
J 25(7): 1517 (fish brain esterases)

Asia
J 25(12): 2527 (brown trout distribution)

Aspinwall, Nevin
J 25(7): 1317 (hybrid fish protein)

Assemblages
J 25(7): 1405 (recurrent group analysis of Gulf of Guinea demersal species)

Asterias (*see* Starfish)

Asterotheca infraspinata (*see* Starsnout, spinycheek)

Asterotheca pentacantha (*see* Starsnout, bigeye)

Atheresthes species
T 34 (systematics)

Atheresthes stomias (*see* Flounder, arrowtooth)

Atnarko River, B.C. (see Bella Coola River system)

Atton, Frederick Mervyn
J 25(7): 1511 (Sask. R. lake sturgeon age & growth)

Aulorhynchus flavidus (*see* Tubesnout)

Australasia
J 25(12): 2527 (brown trout distribution)

Autolysis (*see* Proteolysis)

B

Babine Lake and River system, B.C.
B 162 : 89, 131, 158 (re B.C. sockeye salmon studies)
T 24 (1961–66 enumeration & sampling data for salmon)

Bacillariophyceae
J 25(8): 1603 (fatty acids)
S 1197 (aldolase activity re phylogeny)

Bacteria (*see also* next heading)
J 25(1): 197 (isolated from 12 diseased species of tropical fishes)
(2): 423 (*Nocardia asteroides* causing brook trout nocardiosis)
(3): 607; (4) : 695, 795 (*Gaffkya homari* pathogenic effects on lobster & crab blood)
(4): 625 (marine heterotrophic, re production of organic matter)
(4): 700 (bactericidal activity of lobster hemolymph serum)
(7): 1521 (*Aeromonas* infection of Great Lakes lampreys & trouts)
(8): 1745 (fish homogenates for experimental growth of *Clostridium botulinum*)
B 162 (causing sockeye salmon diseases)
S 1229 (enzymatic oxidation of betaine by *Achromobacter*)
1258 (causing trout skin lesions)

Bacteria in fish processing and products (*see also* Antibiotics; Preservatives; *also* names of bacteria genera)
J 25(3): 547 (*Clostridium botulinum* growth & spore production)
(8): 1745 (experimental culture of *C. botulinum*)
A 77 (bacterial spoilage & its control)

Bactericides (*see also* Antibiotics; Preservatives)
S 1194 (in marine planktonic algal extracts)

Bait
CJG 14 : 30 (Nfld. landings of capelin for)

Balaenoptera acutorostrata (*see* Whale, minke)

Balaenoptera borealis (*see* Whale, sei)

Balaenoptera musculus (*see* Whale, blue)

Balaenoptera physalus (*see* Whale, fin)

Balanus (*see* Barnacle)

Ball, David Stephen
J 25(12): 2739 (NE Pac. phosphate & silicate distribution)

Ball, Edward Arthur Robert
CNS 26 (1957–63 B.C. chum salmon catches)

Ball, Robert Cragin
J 25(7): 1323 (lactate dehydrogenase in trouts)

Bankia setacea (wood-boring mollusc) (*see also* Shipworm)
J 25(5): 853 (glucose metabolism in caecum)

Banks Island, Canadian arctic
J 25(12): 2575 (physics & chemistry of some fresh waters)

Barium compounds
A 85 (in freshwater fishmeals)

Barnacle
J 25(6): 1161 (*Balanus balanoides* susceptibility to parasitic isopod *Hemioniscus balani* infection)
(12): 2633 (differences resulting from *B. balanoides* transplantation)
(12): 2707 (new records of *Conchoderma virgatum* in NW Atl.)

Barracuda, Mexican (*Sphyraena ensis*)
J 25(9): 1987 (red & white muscle temperature of recently caught)

Barracudina, ribbon (*Notolepis rissoi rissoi*)
T 11 (in B.C. experimental midwater trawling)

Barracudina, slender (*Lestidium ringens*)
T 11, 81 (in B.C. experimental trawling)

Barreleye (*Macropinna microstoma*)
T 11 (in B.C. experimental midwater trawling)

Barrett, Burdette Eugene
J 25(12): 2721 (Greenland halibut in Bay of Fundy)

Barrett, Izadore
S 1204 (scombroid fishes serum transferrin polymorphism)

Bass, black (*see* Bass, largemouth)

Bass, largemouth (*Micropterus salmoides*) (black bass)
J 25(1): 49 (dissolved O_2 & CO_2 re juvenile swimming performance)
(2): 294 (gill-raker counts re feed habits)
(6): 1199 (low temperature effects on feeding in 3 Ont. localities)
(12): 2711 (muscle creatine kinase localization)

Bass, rock (*Ambloplites rupestris*)
J 25(2): 294 (gill-raker counts re feed habits)
(6): 1133 (diel feeding habits)
(6): 1199 (low temperature effects on feeding in 3 Ont. localities)
(8): 1739 (spinal ganglia position re taxonomy)

Bass, sea (*see* Sea bass)

Bass, smallmouth (*Micropterus dolomieui*)
J 25(6): 1199 (low temperature effects on feeding in 3 Ont. localities)

Bass, white (*Roccus chrysops*)
A 100 (recent range extension into Man.)

Bathophilus flemingi (*see* Dragonfish, highfin)

Bathyagonus nigripinnis (*see* Poacher, blackfin)

Bathylagus milleri (*see* Blacksmelt, stout)

Bathylagus ochotensis (*see* Blacksmelt)

Bathylagus pacificus (*see* Blacksmelt, slender)

Bathymaster signatus (*see* Searcher)

Bathymetry (*see* Hydrography; Limnology; Oceanography)

Bay of ..... (*see* name of bay)

Beamish, Frederick William Henry
J 25(5): 837 (cod glycogen & lactic acid re exercise)

Bears
B 162: 84 (sockeye salmon predators)

Beckett, James Stafford
J 25(1): 177 (harpoon adapter)
(12): 2707 (*Conchoderma virgatum* in NW Atl.)

Abbreviations: J — Journal; B — Bulletin; AR — Annual Report; R — Review; *Circular series*: CDG — Dartmouth; CHN — Halifax; CJG — St. John's; CNG, CNS — Nanaimo; CSG — St. Andrews; CVG — Vancouver; T — Technical Reports; MSP — Miscellaneous Special Publications; S — Studies; A — Interpretive Articles.

Beef
J 25(3): 605 (ultrasonic effects as test for fresh & frozen flesh quality)
A 76 (summary of above)

Behaviour (*see also* Activity; Diel habits; Feed; Life history; Light, reaction to; Migration; Salinity, reactions to; Schooling; Sound, reactions to; Swimming; Temperature, water (reactions to); etc.)
J 25(1): 1 (competitive & feeding, of hatchery vs. wild Atl. salmon parr in aquaria)
(3): 485 (spawning, of sockeye salmon on Alaska lake beaches)
(3): 589 (of Pac. herring schools towards midwater trawl)
(6): 1115 (sounding reaction of kokanee & sockeye salmon)
(7): 1453 (station permanence in juvenile chinook salmon & steelhead trout)
(9): 2005 (social, among juvenile chinook salmon)
(10): 2123 (underwater observation of scallop)
(11): 2387 (aggression & social hierarchy in starved young Atl. salmon)
(12): 2677 (brook trout lateral line response re DDT)
(12): 2703 (blackspotted stickleback reproductive isolating mechanisms)
S 1252 (rainbow trout avoidance reactions to zinc sulphate solutions)

Bell, Gordon Russel
J 25(6): 1247 (transamination in salmon tissues)
(11): 2505 (^{14}C in *Daphnia pulex*)

Bella Coola River system, B.C.
J 25(4): 757 (marine mortality schedules of pink salmon)

Belle Isle, Strait of
J 25(12): 2749 (possible effect of harbour seal bounty re Atl. cod codworm infestation)
T 27 (summer cod fishery biological data)

Belwood, Lake (reservoir), Ont.
J 25(6): 1229 (phytoplankton ecology)

Benthos
J 25(6): 1181 (upper Great Lakes benthic environment subdivisions)
(8): 1737 (computer programs for summarizing quantitative data)
(9): 1803 (caloric content of standing crop)
(12): 2665 (species associations of Oregon coast fishes)
(12): 2683 (development on an artificial marine reef)
T 3 (Oozy Creek, P.E.I.)
25, 35, 59, 60, 73 (quantitative investigations, Strait of Georgia)
76 (tidal Ostra Lake, N.S.)
S 1223 (seasonal variability of food in coastal environment)
A 108 (1966 Canadian ICNAF studies on Atl.)

Bentley, Robert John
J 25(9): 1803 (invertebrate caloric content)

Bering Sea (*see also* Oceanography, N. Pac. Ocean)
T 18 (shrimp explorations, 1957–63)
75 (winter oceanographic conditions, 1966)

Berkeley, Cyril
J 25(1): 205 (Vancouver, B.C., earthworms)
S 1219 (Polychaeta checklist (Errantia) from B.C. since 1923)
1243 (Polychaeta (Sedentaria) checklist)

Bernard, Frank Rheinhold
J 25(3): 541 (*Polinices lewisi* aquiferous system)
(7): 1509 (new species: *Cyclopecten carlottensis*)
T 2 (W Canada recent marine Mollusca checklist & bibliography)
42 (naticid clam drill biology)

Berst, Alfred Hewitt
J 25(12): 2643 (furunculosis-infected brook trout)

Betaine
S 1229 (enzymic oxidation by *Achromobacter*)

Bibliography
J 25(5): 1039 (re *Anonyx*, particularly *A. nugax*, amphipods)
B 162 : 405 (sockeye salmon studies)
T 1 (131 references, for Dungeness crab)
2 (B.C. marine Mollusca)
28 (*Anguilla* eel species)
55 (re identification of B.C. marine zooplankton)
83 (parasites & diseases of Atl. salmon)

Bideford River, P.E.I.
J 25(12): 2725 (lobsters overwintering in burrows)

Biely, Jacob
S 1221 (fishmeal supplementation of chicken breeder rations on hatchability)
A 85 (freshwater fishmeals nutrient composition)

Bigeye (*see* Pollock, walleye)

Bilinski, Edward
J 25(8): 1555 (starvation re rainbow trout free fatty acids)
S 1248 (algal phospholipase C, properties)

Billaud, Vera Alexander
J 25(10): 2101 (nitrogen fixation and sources in subarctic lake)

Bilton, Hebert Thomas
J 25(5): 1067 (ageing salmon by otoliths & scales)
(9): 1971 (ageing chinook salmon from scales)
(9): 1993 (3rd-year pink salmon)
CNS 26 (1957–63 B.C. chum salmon catches)
T 10 (1965 & 1966 Schulbuckhand & Williams creeks, B.C., sockeye)

Bioassay (*see* Analysis methods; *also* purpose of assay)

Biochemistry (*see also* types and names of organism, their organs and functions)
R 1965–1966: 32, 78 (summary of some Board investigations)
T 31 (Atl. mackerel)

Biomass (*see* Benthos; Matter, particulate; Productivity, primary)

Biosynthesis (*see also* Photosynthesis; Productivity, primary)
J 25(2): 431 (of sterones by Atl. herring interrenal tissue)
(4): 625 (production & mineralization of marine organic matter)
(6): 1247 (transaminases distribution in Pac. salmon tissues)
S 1236 (of lipids from added substrates by Atl. salmon sperm)
1244 (of protamine during salmonid spermatogenesis)

Biotin (*see* Vitamin B group)

Birds
S 1201 (ptarmigan off N Labrador)
1203 (positional distribution of monoenoic fatty acids in duck triglycerides)
1226 (fatty acids positional distribution in gull & cormorant triglycerides)

Bishop, Daniel Magnus
J 25(5): 921 (frozen cod muscle TMA)

Bivalves (*see* Mollusca; *also* names of individual species, e.g., Clam; Mussel; Oyster; Scallop)

Blackcod (*see* Sablefish)

Blackford, Bradford Lloyd
T 26 (S Gulf of St. Lawrence oceanographic observations)

Blacksmelt (*Bathylagus ochotensis*)
T 11 (in B.C. experimental midwater trawling)

Blacksmelt, slender (*Bathylagus pacificus*)
T 11 (in B.C. experimental midwater trawling)

Blacksmelt, stout (*Bathylagus milleri*)
T 11 (in B.C. experimental midwater trawling)

Bladder, gall
J 25(9): 1797 (dieldrin accumulation in goldfish, after aldrin ingestion)

Bladder, swim
J 25(3): 469 (re sound-scattering layers of fishes)
(6): 1115 (histology re sounding response of kokanee & sockeye salmon)
(7): 1485 (function in longnose dace buoyancy adjustment)
(8): 1698 (gas re respiratory quotient errors)

Blair, Arthur Avery
A 113 (pink salmon in Nfld.)

Blaxland, Martin
A 115 (sea's food chain)

Blennies (general)
T 22, 30, 46, 62 (in B.C. experimental trawling)

Blenny, decorated (*Chirolophus polyactocephalus*)
T 46 (in B.C. experimental groundfish trawling)

Bligh, Emerson Graham
A 85 (freshwater fish meals nutrient composition)

Bloater (*Leucichthys hoyi*)
J 25(4): 667 (re Great Lakes species succession & exploitation)
(8): 1667 (cytotaxonomic relation to other Great Lakes coregonids)
(10): 2111 (scales annulus formation in artificially reared, also in hybrid with lake herring)

Blood; Blood constituents (*see also* Heart; Respiration; Serology)
J 25(1): 15 (*p*H & lactic acidosis of channel catfish in anoxia)
(1): 25 (M.S. 222 anesthetic concentration in rainbow trout)
(1): 71 (fluorimetric determination of cortisol in salmonid)
(1): 151 (hematological changes in coho salmon deficient in folic acid)
(1): 173 (hematological correlations in rainbow trout)
(3): 473 lactate re exercised salmon mortality)
(3): 541 (role in *Polinices* podium expansion)

(3): 603 (rainbow trout disturbance effects on)
(3): 607; (4): 695, 795 (*Gaffkya homari* pathogenic effects on lobster & crabs)
(4): 695 (bactericidal activity of lobster hemolymph serum)
(5): 837 (glycogen of Atl. cod after exercise)
(7): 1465 (metopirone effect on cortisol concentration in salmon & trout plasma)
(7): 1497 (prolactin effects on osmolarity of hypophysectomized goldfish plasma)
(8): 1555 (starvation effect on free fatty acids of rainbow trout plasma)
(8): 1651 (inorganic iodide binding in plasma proteins)
(9): 1797 (dieldrin accumulation in goldfish, after aldrin ingestion)
(11): 2477 (hemoglobin electrophoresis of 28 rockfish species re systematics)
(12): 2549 (skate interrenalectomy & stress re some components of)
(12): 2651 (Atl. salmon: hemoglobin multiplicity increase re fish length)
S 1214 (Atl. oyster hemolymph hemagglutinins)

Blubber
S 1193 (pristanic & phytanic fatty acids of fin whale oil)
1226 (positional distribution of fatty acids in triglycerides of seals and sei whale)
1228 (isoprenoid fatty acids of whale & seal fats, re feed)

Bluegill (*Lepomis macrochirus*) (bluegill sunfish)
J 25(2): 294 (gill-raker counts re feed habits)
(2): 373 (retinomotor rhythms)
(4): 615 (enzymatic properties of brain acetylcholinesterase)
(6): 1133 (diel feeding habits)
(6): 1199 (low temperature effects on feeding in 3 Ont. localities)
(7): 1517 (electrophoretic separation of brain esterases)
(8): 1571 (liver phosphatáses degrade organophosphate insecticides)

Boats: Vessels
CSG 52 (antifouling coatings for)
A 88 (same as CSG 52 above)

Bocaccio (*Sebastodes paucispinis*)
J 25(11): 2477 (proteins electropherograms re rockfishes systematics)
T 7, 11, 16, 22, 30, 46, 56, 62, 81 (in B.C. experimental or commercial trawling)

Bone (*see* Cranium; Osteology; Vertebrae)

Bonito, Pacific (*Sarda chiliensis*)
S 1204 (population units study by serum transferrin polymorphism)
A 90, 103 (fishery trend along N America Pac. coast)

Booke, Henry Edward
J 25(8): 1667 (Great Lakes coregonine fishes, cytotaxonomy)

Boops boops
J 25(7): 1405 (Gulf of Guinea)

Borden, Robert Keith
S 1246 (nucleotide synthesis)
1247 (nucleotide synthesis)

Borodulina infans; *B. gilli* (*see* Eel, snipe)

Boron compounds
A 85 (in freshwater fishmeals)

Bos taurus (*see* Steer)

Bothern, C.R.
J 25(6): 1115 (kokanee & sockeye sounding response)

Bothrocara brunneum (*see* Eelpout, twoline)

Bothrocara remigera (*see* Eelpout, longfin)

Bottom sediments (*see* Sediments)

Botulism
J 25(3): 547 (*Clostridium botulinum* growth & spore production)
(8): 1745 (fish homogenates as substrate for investigations on Type E *C. botulinum*)

Bouck, Gerald Ray
J 25(7): 1323 (trout lactate dehydrogenase)

Boulva, Jean
J 25(7): 1501 (F) (*Salvelinus namaycush* in marine waters)

Bounty
J 25(12): 2749 (on harbour seals: possible effect on Atl. cod codworm infestation)

Bourne, Neil
T 15 (hydraulic clam rake digging efficiency trials)

Bowfin (*Amia calva*)
J 25(6): 1199 (low temperature effects on feeding in 3 Ont. localities)

Boyd, John William
J 25(8): 1745 (fish homogenates as substrates)
(8): 1753 (ethylenediaminetetraacetic acid & chlortetracycline in fish preservation)

Brachydanio albolineatus (*see* Danio, pearl)

Brachydanio negrofasciatus (*see* Danio, spotted)

Brachydanio rerio (*see* Zebrafish)

Brain
J 25(4): 615 (acetylcholinesterase properties of fish)
(6): 1247 (tissues of Pac. salmon re transaminases activity)
(7): 1517 (electrophoretic separation of esterases)
(9): 1797 (dieldrin accumulation in goldfish, after aldrin ingestion)

Brawn, Vivien Mavis
J 25(9): 1803 (invertebrate caloric content)

Brett, John Roland
A 116 (fish respirometer)

Brill, Pacific (*see* Sole, petrale)

Bristol Bay, Alaska
J 25(6): 1219 (oceanic mortality estimation of sockeye salmon from)

British Columbia (*see also* Oceanography, B.C. coast; *also* names of individual localities & bodies of water; *also* names of commercial fishery species)
J 25(1): 33 (juvenile steelhead & cutthroat trout distribution within SW streams)
(1): 81 (limnology of 3 SW lakes re trout mortality)
CNG 85 (1967 shrimp exploration)
86 (1968 herring spawning)
T 2 (distributional checklist & bibliography of marine Mollusca)
7, 56 (catch & effort statistics of commercial trawl fishery, 1966, 1967)
11 (exploratory midwater trawling off Queen Charlotte Is.; sound-scattering layers investigation)
12 (catch statistics for Pac. cod commercial trawling, 1935–65)
13 (trawlers & trawling gear)
16 (catch rates, size composition, & sex ratio of experimentally trawled Pac. ocean perch, 1966)
19, 89 (summary report of commercial trawling, & investigational aspects, 1966, 1967)
22, 81 (experimental groundfish trawling off W coast Vancouver Is., 1967, 1968)
23 (length composition of commercially trawled Pac. cod, 1951–66)
30, 46, 62 (experimental groundfish trawling in Queen Charlotte Is. region, 1963–66, 1967, 1968)
S 1219 (Polychaeta (Errantia) checklist from 1923)
1243 (Polychaeta (Sedentaria) checklist from 1923)

Brockerhoff, Hans
S 1203 (isomer distribution of monoeonic fatty acids)
1226 (fatty acids positional distribution)
1233 (fatty acids incorporation into mammals triglycerides & phospholipids)
1250 (pancreatic lipase substrate specificity)

Brooke, Richard O.
J 25(11): 2453 (dimethyl sulfide & clam odor)

Brosme brosme (*see* Cusk)

Brotulid, rednose (*Cataetyx rubrirostris*)
J 25(12): 2665 (associations with other fishes off Oregon coast)

Brown, Seward Ralph
J 25(3): 523 (chlorophyll derivatives)

Brownell, Robert Leo Jr.
J 25(12): 2561 (fish otoliths in cetacean stomachs)

Browning of flesh (Maillard browning)
A 79 (cause & avoidance)
80 (re nutritive value of fish flesh)

Bruce, David Lorne
S 1194 (two *Isochrysis galbana* antibacterial products)

Brunel, Pierre
J 25(5): 943 (NA Atl. & Arctic coast Amphipoda)
T 47 (tabular data from *Anonyx* species)

Bryozoa
J 25(11): 2269 (description & distribution of 93 species, arctic Canada)
T 43 (on Irish moss)

Buccinum undatum (*see* Whelk, rough)

Budd, J. C.
J 25(11): 2257 (L. Manitou marked lake trout survival)

Buerkle, Udo
J 25(6): 1155 (cod auditory thresholds)

Bullhead (*Cottus scorpius*)
J 25(12): 2711 (muscle creatine kinase localization)

Bullhead, brown (*Ictalurus nebulosus*)
J 25(6): 1199 (low temperature effects on feeding in 3 Ont. localities)
(7): 1521 (infection by *Aeromonas*)
(8): 1739 (spinal ganglia position re taxonomy)

Bullock, Graham Lambert
J 25(2): 383 (infectious pancreatic necrosis: virus-free trout selection)

Buoyancy (of fish) (*see* Bladder, swim)

Burbot (*Lota lota*) (ling; maria)
J 25(1): 169 (pesticide residues in oils & meals)
(4): 667 (re Great Lakes species succession & exploitation)
(8): 1651 (plasma protein-bound inorganic iodide)
(11): 2523 (*Triaenophorus nodulus* parasite in)
T 33 (in Great Slave Lake fishery)
S 1226 (fatty acids positional distribution in liver triglycerides)
A 85 (nutrient composition of meal as poultry feed)

Burnett, Carienne Doris
T 57 (Bay of Fundy herring length & age distribution)

Bursa, Adam Stanislaw
J 25(6): 1269 (starch in oceans)

Burt, Michael David Brunskill
J 25(11): 2521 (microturbellarian in oysters off P.E.I.)

Butler, Jerry Allan
J 25(8): 1621 (Sevin effects on clams)

Butler, Terrance Henry
CNG 85 (1967 B.C. coast shrimp exploration)
T 1 (Dungeness crab bibliography)
18 (Gulf of Alaska & Bering Sea shrimp exploration & fishing)
61 (shrimp sampling & temperature data off B.C., 1966, 1967)
A 104 (good shrimping areas discovered)

Butterfish, spotted (*Scatophagus argus*)
J 25(1): 197 (microorganisms isolated from diseased)

Buttkus, Hans
S 1195 (myosin reaction with malonaldehyde)

Buttle Lake, B.C.
J 25(9): 1997 (planktonic prickly sculpin diel limnetic occurrence)

C

Cabezon (*Scopaenichthys marmoratus*)
J 25(2): 332 (host to parasitic chondracanthid copepod)

Caddy, John Frederick
J 25(10): 2123 (underwater observations of scallops)
S 1256 (paralytic shellfish poison in *Buccinum*)

Cadmium compounds
J 25(4): 639 (catalyzing fatty fish flesh oxidative randicity)

Caecum
J 25(5): 853 (glucose metabolism in *Bankia setacea*)

Caillouet, Charles Wax, Jr.
J 25(1): 15 (channel catfish lactic acidosis)

Calanus species
CNG 84 (popular description of some NE Pac. Ocean)

Calcium compounds
A 85 (in freshwater fishmeals)

Caligus curtus (a parasitic copepod)
J 25(9): 1923 (review & description)

Caloric content
J 25(9): 1803 (of marine benthic & epibenthic invertebrates)
(11): 2515 (of some invertebrates in Lake Mendota)

Cambarus (species) (*see* Crayfish)

Campbell, Gordon
J 25(2): 423 (brook trout nocardia infection)

Campbell Lake, B.C.
J 25(9): 1997 (planktonic prickly sculpin diel limnetic occurrence)

Cancer borealis (*see* Crab, Jonah)

Cancer irroratus (*see* Crab, rock)

Cancer magister (*see* Crab, Dungeness)

Cancer oregonensis
T 30 (in B.C. experimental trawling)

Canning; Canned products
B 162 : 43 (history of sockeye salmon)
CVG 38 (salmon: clarifying waste-water for solids and oil recovery re pollution minimization)
T 14 (clarification of waste water other than stickwater from B.C. fish plants)

Capelin (*Mallotus villosus*)
CJG 14, 15 (Nfld. surveys, 1966, 1967; landings, 1957–65)
S 1228 (isoprenoid fatty acids of oil, re feed)
1255 (biology review in Canadian NW Atl.)
A 108 (1966 Canadian ICNAF studies: commercial catches; ages; stocks)

Carapace (*see* Chitin; Exoskeleton)

Carassius auratus (*see* Goldfish)

Carbohydrates (*see also* Cellulose; Glucose; Glycogen; Starch; Sugars)
J 25(4): 625 (re marine heterotrophic bacteria activity)
B 167 : 173, 231, 235 (determination in sea water)

Carbon ^{14}C isotope (*see Note to heading Isotopes*)
J 25(11): 2505 (use of liquid scintillation counter for measuring self-absorption in materials)
B 167 : 267 (determination of uptake re marine photosynthesis)

Carbon content (*see also* Productivity, primary; *also* Carboyhdrates; Carbon dioxide; Carbonates; etc.)
J 25(6): 1181 (upper Great Lakes benthic sediments)
B 167 : 153, 207 (soluble & particulate organic carbon determination in sea water)

Carbon dioxide
J 25(1): 49 (effect of dissolved, on juvenile largemouth bass & coho salmon swimming speed))
(4): 625 (uptake & release re production & mineralization of marine organic matter)
(12): 2603 (re goldeye respiration)
B 167 : 27, 35 (determination in sea water)
S 1237 (fixation by Atl. cod sperm)

Carbonates; Biocarbonates
B 167 : 27 (determination in sea water)

Carcharhinus species (*see* Shark, reef)

Carcharhinus falciformis (*see* Shark, sickle)

Carcharhinus obscurus (*see* Shark, dusky)

Careproctus melanurus (*see* Snailfish, blacktail)

Caristius macropus (*see* Manefish)

Carlson, Charles Philip
J 25(2): 383 (infectious pancreatic necrosis: virus-free trout selection)

Carotenoid pigments (see Chlorophylls; Pigments)

Carp (*Cyprinus carpio*)
J 25(4): 667 (re Great Lakes species succession & exploitation)
(8): 1651 (plasma protein-bound inorganic iodide)
(12): 2711, 2715 (muscle creatine kinase)
B 165 (biology, distribution, commercial fishery, sport fishery, regulations, etc.)
A 100 (recent range extension into Man.)

Carrothers, Percival John Godber
B 163 (instrumentation for engineering study of otter trawls)

Carter, Neal Marshall
B 164 (index & list of FRB publications 1901–64)

Castell, Charles Howell
J 25(4): 639 (heavy metal ions & fish muscle rancidity)
(5): 921 (frozen cod muscle trimethylamine)

Castell, John Daniel
S 1192 (gas chromatography of fatty acids)

Cataetyx rubrirostris (*see* Brotulid, rednose)

Cataraqui Creek (Little), Ont.
J 25(6): 1199 (water temperature effects on fish feeding)

Catches (*see also* Angling; Fisheries; Trawl)
J 25(2): 209 (of brook trout as affected by stream ponding)
(3): 457 (B.C. coast midwater trawl, re sound-scattering layers)
(4): 667 (re Great Lakes species succession & exploitation)
(10): 2183 (commercial, of Nfld. & Labrador salmon)
B 162 : 43 (sockeye salmon)
165 : 39 (carp in Canadian provinces since 1908)
166 : 42, 68 (eels in E Canada)
CJG 14, 15 (Nfld. groundfish landings, 1966, 1967)
CNS 26 (age, size, & sex ratios in B.C. chum salmon 1957–63)
T 7, 19, 56, 89 (& catch effort statistics of 1966 & 1967 B.C. trawl fishery)
11 (B.C. experimental midwater trawling off Queen Charlotte Is., 1964, 1965)
12 (statistics of Canadian & U.S. Pac. cod trawl)
16 (catch rates of Pac. ocean perch during NE Pac. experimental fishing 1966)
22, 81 (experimental groundfish trawling off W coast Vancouver Is. 1967, 1968)
23 (length composition of B.C. commercial trawled Pac. cod, 1951–66)
29 (commercial Canadian, of Atl. salmon 1949–65)

30, 46, 62 (experimental groundfish off Queen Charlotte Is., 1963–66, 1967, 1968)
39 (computer tape system for processing data)
58 (of Nfld. herring re stocks distribution & abundance)
S 1207 (American plaice diurnal variation of, off Grand Bank)
1209 (offshore fishing effect on inshore Labrador cod fishery)
1235 (mathematics of quick methods for estimating size limits changes effect on)
A 86 (of Pac. salmon & steelhead trout during INPFC 1966 research)
90, 103 (of various fishes in E Pac.)
91 (of B.C. bottom fishes for mink feed, 1951–66)
105 (of B.C. herring re miles of spawn, 1955–67)
108 (commercial & research, re 1966 Canadian ICNAF studies)

Catfish, channel (*Ictalurus punctatus*)
J 25(1): 15 (blood lactic acidosis)
(4): 615 (enzymatic properties of brain acetylcholinesterase)
(7): 1517 (electrophoretic separation of brain esterases)
(8): 1571 (liver phosphatases degrade organophosphate insecticides)

Catfish, stripped (*see* Eel, barbel)

Catostomus catostomus (*see* Sucker, longnose)

Catostomus commersoni (*see* Sucker, white)

Catostomus macrocheilus (*see* Sucker, large-scale)

Caulfield, William
J 25(4): 823 (coho fry counting in small streams)

Cellulose (*see also* Carbohydrates)
J 25(5): 853 (digestion metabolism in marine wood borer)

Census, creel (*see* Angling)

Centropristes striatus (*see* Sea bass, black)

Cephalopoda
CNG 84 (popular description of some NE Pac. Ocean)

Cerium compounds
J 25(4): 639 (re marine flesh oxidative rancidity)

Cestoda (*see* Tapeworms)

Cetaceans (*see also* names of species)
J 25(12): 2561 (feeding habits from fish otoliths in stomach)

Chaenophryne parviconus (*see* Dreamers)

Chaetognatha (*see also Sagitta*)
CNG 84 (popular description of some NE Pac. Ocean)
T 55 : 129 (identification of B.C.)

Chandler, Ross Allan
S 1256 (paralytic shellfish poison in *Buccinum*)

Chapman, Donald Wallace
J 25(7): 1453 (salmon & trout permanence of station)

Char, Dolly Varden (*see* Dolly Varden)

Chaston, Ian
J 25(6): 1285 (light re brown trout activity)

Chauliodus macouni (*see* Viperfish, fanged)

Chaulk, Raymond
T 58 (Nfld. herring catches & landings)

Checklists (*see also* Lists)
T 2 (B.C. marine Mollusca)
S 1219 (Polychaeta (Errantia) recorded from B.C. since 1923)
1243 (Polychaeta (Sedentaria) recorded from B.C. since 1923)

Chicken (*Gallus domesticus*)
J 25(8): 1651 (plasma protein-bound inorganic iodide)
S 1221 (fish meal in breeder ration effect on hatchability)
1233 (fatty acids incorporation, through feed, into mink tissues)
A 85 (nutrient composition of freshwater fishmeals as feed for)

Chignik Lakes, Alaska
J 25(1): 157 (*Mesidotea entomon* biology)

Chilipepper (*Sebastodes goodei*)
J 25(11): 2477 (proteins electropherograms re rockfishes systematics)
T 46 (in B.C. experimental trawling)

Chilko Lake, B.C.
B 162 : 318 (re sockeye salmon studies)

Chilling (*see also* Icing; Refrigeration)
J 25(4): 817 (rapid hypoxanthine accumulation in iced redfish fillets)

Chimaera, deepwater (*Hydrolagus affinis*)
J 25(11): 2365 (2 new species of tapeworms from)

Chionoecetes opilio (*see* Crab, spider)

Chirolophus polyactocephalus (*see* Blenny, decorated)

Chironomidae (*see also* Midges)
T 43 (larvae on Irish moss)

Chitin
B 167 : 237 (determination of particulate, in sea water)

Chitonotus pugetensis (*see* Sculpin, roughback)

Chlamys islandicus (*see* Scallop, Iceland)

Chlorophyceae
J 25(8): 1603 (fatty acids re taxonomy)

Chlorophylls
J 25(3): 523 (absorption coefficients of *a*, *b*, and 12 derivatives)
(10): 2101 (re algal bloom in subarctic lake)
B 167 : 185 (determination in sea water)
S 1223 (*a*, re seasonal variations in marine benthos feed availability)
1254 (phytoplanktonic, as possible precursor of shale isoprenoid fatty acids)

Cholesterol (*see* Sterols)

Choline and derivatives
J 25(4): 615 (fish brain acetylcholinesterase enzymatic properties)
(7): 1517 (electrophoretic separation of brain esterases)
(10): 2083 (fatty acids distribution in Atl. cod flesh)

Chondracanthidae (parasitic copepods)
J 25(2): 321 (3 species redescribed; 2 new species described)

Chondrococcus columnaris
B 162 : 92 (cause of sockeye salmon "high temperature disease")

Chondrus crispus (*see* Irish Moss)

Chorilia longipes (*see* Crabs, spider)

Chromatography (general)
S 1192 (monoethylenic fatty acids isomers structure & other effects on GLC)
1225 (chain-length overlap problem in GLC)
1238 (retention-times prediction in fatty acid GLC)
1251 (recovery of microquantities of steroids after thin-layer)
A 101 (relative merits of different "Carbowax" types for GLC)

Chromium compounds
J 25(4): 639 (re marine flesh oxidative rancidity)
A 85 (in freshwater fishmeals)

Chromosomes (*see also* Cytology)
J 25(5): 1091 (method for preparing dry mounted, from teleost fishes)
(8): 1667 (cytotaxonomic relations in Great Lakes coregonids)

Chorney, Victoria
S 1198 (growth of *Hemiselmis virescens*)

Chrosomus eos (*see* Dace, northern redbelly)

Chrysemys picta (*see* Turtle, painted)

Chrysophyceae
J 25(8): 1603 (fatty acids)
S 1194 (2 antibacterial products from *Isochrysis galbana*)
1197 (aldolase activity re phylogeny)

Chub (*Leuciscus cephalus*) (*Mugil cephalus*)
J 25(12): 2711 (muscle creatine kinase localization)

Chub, creek (*Semotilus atromaculatus*)
J 25(6): 1199 (low temperature effect on feeding in 3 Ont. localities)

Chub, peamouth (*Mylocheilus caurinum*)
J 25(7): 1317 (muscle proteins inheritance in hybrids with redside shiner)

Chubs (*see* Cisco species)

Churchill, David Nelson
J 25(4): 733 (Nfld. trap-caught cod quality after single & double freezing)

Ciliata
J 25(8): 1749 (*Cyclotrichium meunieri* cause of red water in Gulf of Maine)

Cisco (*see* Herring, lake; Tullibee)

Cisco, blackfin (*Leucichthys nigripinnis*)
J 25(4): 667 (re Great Lakes species succession & exploitation)

Cisco, deepwater (*Leucichthys johannae*)
J 25(4): 667 (re Great Lakes species succession & exploitation)

Cisco, longjaw (*Coregonus alpenae*)
J 25(4): 667 (re Great Lakes species succession & exploitation)

Cisco, shortjaw (*Leucichthys zenithicus*)
J 25(4): 667 (re Great Lakes species succession & exploitation)
(8): 1667 (cytotaxonomic relation to other Great Lakes coregonids)

Cisco, shortnose (*Coregonus reighardi*)
J 25(4): 667 (re Great Lakes species succession & exploitation)
(8): 1667 (cytotaxonomic relation to other Great Lakes coregonids)

Citharichthys sordidus (*see* Sanddab, Pacific)

Citharichthys stigmaeus (*see* Sanddab, speckled)

Cladocera
J 25(11): 2505 (*Daphnia pulex* used in testing measurement of ^{14}C incorporation)
(11): 2515 (*Daphnia* caloric value)
T 55 : 27 (identification of B.C.)

Claggett, Freddie Gene
CVG 38 (waste-water clarification)
39 (fishmeal pilot plant)
40 (antioxidants re herring meal)
T 14 (B.C. fishing plant waste-water clarification)
A 112 (fishmeal pilot plant)

Clam (a Pacific) (*Tresus nuttalli*)
T 42 (clam borer predation on)

Clam, butter (*Saxidomus giganteus*)
T 15 (fork vs. hydraulic rake digging efficiency)
42 (clam drill predation on)

Clam, cockle (*Clinocardium nuttalli*) (basket cockle)
J 25(8): 1621 (Sevin insecticide effect on survival & growth)
T 42 (clam drill predation on)

Clam, horse (*Tresus capax*)
T 15 (fork vs. hydraulic rake digging efficiency)

Clam, Japanese little-neck (*see* Clam, Manila)

Clam, little-neck (*Protothaca staminea*)
T 15 (fork vs. hydraulic rake digging efficiency)
42 (clam drill predation on)

Clam, Manila (*Venerupis japonica*) (Japanese little-neck clam)
T 42 (clam drill predation on)

Clam, soft-shell (*Mya arenaria*)
J 25(2): 267 (occurrence & retention of thetin derivative from feed)
(11): 2453 (significance of dimethyl sulphide odour)
A 84 (effect of various pollutants on production)

Clam drill (*Polinices lewisi*)
J 25(3): 541 (aquiferous system for podium expansion)
T 42 (biology)

Clarke, Arthur Hadleton, Jr.
S 1199 (ancient oyster & bay scallop shells from Sable Is.)

Clarke, William Craig
J 25(7): 1497 (salmon pituitary "prolactin")

Clinocardium ciliatum (a cockle)
J 25(9): 1803 (caloric content)

Clinocardium nuttalli (*see* Clam, cockle)

Clione limacina (*see* Sea butterfly)

Clostridium botulinum (*see* Botulism)

Clupea harengus (*harengus*) (*see* Herring, Atlantic)

Clupea pallasii (*see* Herring, Pacific)

Cobalt compounds
J 25(4): 639 (catalyzing fatty fish flesh oxidative rancidity)
B 167 : 159 (cyanocobalamine (vitamin B_{12}) determination in sea water)

Cobb, John Stanley
J 25(10): 2251 (lobster larvae moult delay)

Coburn, Arthur Stephen
T 10 (1965 & 1966 Schulbuckhand & Williams creeks, B.C., sockeye)

Cockle, basket (*see* Clam, cockle)

Cockroach (*Periplaneta americana*)
J 25(8): 1651 (plasma protein-bound inorganic iodide)

Cod, Atlantic (*Gadus morhua*) (*see also* Codling)
J 25(2): 299 (rigor & freezing–thawing processes on quality of refrozen)
(3): 555 (analysis of S Gulf of St. Lawrence population)
(4): 639 (catalysis of flesh oxidative rancidity by metal ions)
(4): 733 (condition of trap-caught, re quality after freezing)
(5): 837 (muscle glycogen & blood lactic acid re exercise)
(5): 921 (nonbacterial trimethylamine production in frozen muscle)
(5): 935 (muscle free amino acid changes in gillnetted)
(6): 1155 (tonic reaction to sound)
(7): 1475 (effect of Na tripolyphospate dip to avoid drip loss in stored unfrozen flesh)
(8): 1525 (quantitative glycogen & ΔTP from frozen muscle)
(10): 2059 (protein extractability re free fatty acids in iced muscle)
(10): 2083 (fatty acids distribution in lipids)
(12): 2623 (cryogenic preservation of sperm)
(12): 2749 (possible effects of harbour seal bounty on Atl. cod infestation by codworm)
CJG 14 (Nfld. fishery & landings, 1956–66)
15 (Nfld. landings, 1952–67)

T 27 (Strait of Belle Isle summer fishery biological data)
68 (fillet analysis for EDTA preservative content)
80 (stocks, Gulf of St. Lawrence & N.S. Banks)
S 1193 (pristanic & phytanic fatty acids of liver oil)
1203 (positional distribution of monoenoic fatty acids in liver triglycerides)
1208 (otolith age validation)
1209 (offshore fishing effect on inshore Labrador fishery)
1226 (fatty acids positional distribution in liver triglycerides)
1228 (isoprenoid fatty acids of liver oil, re feed)
1231 (uricolytic enzymes in sperm)
1237 (CO_2 fixation by sperm)
A 98 (composition of protein concentrate from fillets)
99 (1952–64 production from ICNAF areas; size & age composition)
108 (1966 Canadian ICNAF studies: catches, ages, lengths, action of trawls)

Cod, black (*see* Sablefish)

Cod, gray (*see* Cod, Pacific)

Cod, longfin (*Antimora rostrata*)
J 25(12): 2665 (associations with other Oregon coast fishes)
T 22, 81 (in B.C. experimental trawling)

Cod, Pacific (*Gadus macrocephalus*) (gray cod; true cod)
J 25(8): 1539 (postmortem muscle glycogen & starch degradation)
(8): 1745 (muscle hydrogenate as substrate for experimental *Clostridium botulinum* growth)
(8): 1753 (preservatives effects on flesh)
CHN 32 (used for Japanese fish paste)
T 7, 11, 16, 19, 22, 30, 46, 56, 62, 81, 89 (in experimental or commercial B.C. trawling)
12 (catch statistics of 1935–65 Canadian & U.S. trawl fishery)
19 : 27 (experiments on embryonic development)
23 (length composition of 1951–66 B.C. trawled)
34 (distribution, stocks, populations, synonymy, systematics)
62 (tumors)
89 : 26 (depth distribution)
A 91 (1951–66 B.C. landings for mink feed)

Codling (*Gadus callarias*)
J 25(12): 2711 (muscle creatine kinase localization)

Codworm (*Phocanema decipiens*) (*Porrocaecum decipiens*)
J 25(12): 2749 (possible effects of harbour seal bounty on Atl. cod infestations by)

Coelenterata
J 25(9): 1803 (caloric content of *Duva multiflora*)
CNG 84 (popular description of NE Pac. Ocean)
T 55 : 11 (identification of B.C.)

Coilia dussumieri (a tropical fish)
J 25(1): 197 (microorganisms isolated from diseased)

Collins, Gerald Bradford
J 25(5): 867 (olfaction/vision in spawning site choice)

Cololabis saira (*see* Saury, Pacific)

Colton, John Bowne, Jr.
J 25(11): 2427 (Gulf of Maine temperatures)

Commensalism
J 25(11): 2521 (a microturbellarian with Atl. oyster)

Commissions (*see* International)

Competition (*see also* Behaviour)
B 162 : 231 (re feed in sockeye salmon lakes)

Composition, chemical (for waters, *see* Limnology; Oceanography; Pollution; *see also* Analysis methods; *also* names of elements)
J 25(11): 2403 (changes during coho salmon parr–smolt transformation)
A 80 (re fish nutritive values)
85 (of freshwater fishmeal, B.C. herring meal)
97, 98 (of herring & Atl. cod products & by-products)

Computer programming (*see also* Mathematical treatment)
T 20 (facilities available at St. Andrews Biological Station)
39 (tape system for processing fisheries data)
40 (for multiple discriminant analysis)
87 (for nonlinear response surfaces analysis)

Concertinafish (*see* Sicklefish)

Conchoderma virgatum (*see* Barnacles)

Condition
T 5 (Atl. herring)
A 98 (fat content of Atl. herring by months for 2 years)

Conger conger (*see* Eel, conger)

Conservation (*see also* Management; Rehabilitation; *also* names of International Commissions)
B 162 (sockeye salmon)
A 63 (Atl. herring)

Contracaecum (*see* Nematoda)

Convict fish (*Abudefduf saxatilis*) (sergeant major)
J 25(1): 197 (microorganisms isolated from diseased)

Cooking
CHN 33, 34 (shrimps for fresh use, freezing or canning)
A 89 (same as CHN 33 above)

Copepoda
J 25(2): 321 (parasitic Chondracanthidae from B.C. fishes)
(9): 1923 (review & description of *Caligus curtus*)
CNG 84 (popular description of some NE Pac. Ocean)
S 1206 (parasitic on Atl. salmon)
T 55 : 33 (identification of B.C.)
73 (in Strait of Georgia benthos biomass)
81 (*Phrixocephalus cincinnatus* on turbot)
A 108 : 17 (*Anomalocera patersoni* habitat)

Copper compounds
J 25(4): 639 (catalyzing marine flesh oxidative rancidity)
B 167 : 115 (determination in sea water)
CSG 52 (in antifouling coatings for boats)
S 1196 (re mining pollution effects on spawning Atl. salmon)
A 85 (in freshwater fishmeals)
88 (same as CSG 52 above)
111 (NTA sequestrering agent to combat pollution from)

Corbett Lake, B.C.
J 25(1): 81 (limnology re trout mortality)

Coregoninae (*see also* species names)
J 25(8): 1667 (cytotaxonomic studies of Great Lakes)

Coregonus (*see* following species, *also Leucichthys* species)

Coregonus artedi(i) (*see* Herring, lake; Tullibee)

Coregonus clupeaformis (*see* Whitefish, lake)

Cornea (*see* Eye)

Cornick, John Walter
J 25(4): 695 (*Gaffkya homari* interaction with *Homarus americanus* defense mechanisms)
(4): 795 (*Gaffkya homari* pathogenicity for *Cancer irroratus*)

Corrections, list of
J 25(8): 1759 (for recent Board publications)

Corticosterone derivatives (*see* Cortisol; Hormones)

Cortisol (*see also* Hormones; Steroids)
J 25(1): 71 (fluorimetric determination in salmonid plasma)
(7): 1465 (metopirone effect on concentration of, in salmon & trout plasma)
S 1250 (sockeye salmon sexual maturation effects on injected radioactive)

Coryphaena hippurus (*see* Dolphin (Pacific))

Coryphaenoides acrolepis (*see* Rattail, roughscale)

Coryphaenoides filifera (*see* Rattail, filamented)

Coryphaenoides pectoralis (*see* Rattail, pointed)

Cottus asper (*see* Sculpin, prickly)

Cottus ricei (*see* Sculpin, spoonhead)

Cottus scorpius (*see* Bullhead)

Counting
J 25(4): 823 (method for coho salmon fry in small streams)

Courtney Lake, B.C.
J 25(1): 81 (limnology re trout mortality)

Cowichan River, B.C.
J 25(3): 599 (chum salmon fry feeding in)

Crab, blue king (*Paralithodes platypus*)
J 25(3): 439 (description of laboratory-reared larvae)

Crab, box (*Lopholithodes mandtii*)
T 30 (in B.C. experimental groundfish trawling)

Crab, Dungeness (*Cancer magister*)
T 1 (131 references, bibliography)
7, 56 (in B.C. commercial groundfish trawling)

Crab, hermit (*Pagurus*)
T 30 (in B.C. experimental groundfish trawling)

Crab, Jonah (*Cancer borealis*)
J 25(3): 607 (lobster pathogen *Gaffkya homari* effect on hemolymph of)

Crab, king (*Paralithodes camtschatica*)
A 90, 103 (fishery increase along B.C. & Alaska coast)

Crab, rock (*Cancer irroratus*)
J 25(3): 607; (4): 795 (lobster pathogen *Gaffkya homari* effect on hemolymph of)

Crab, spider (*Chionoecetes opilio*)
J 25(8): 1729 (O_2 consumption at low temperature)
(8): 1733 (temperature resistance)

Crabs, spider (*Oregonia gracilis*; *Chorilia longipes*)
T 30 (in B.C. experimental trawling)

Crab, toad (*Hyas coarctatus*)
J 25(3): 607 (lobster pathogen *Gaffkya homari* effect on hemolymph of)

Cranium
J 25(9): 1843 (of new genus & species of fossil sea lion)
S 1240 (measurements of stranded Cuvier's beaked whales)

Crappie, black (*Pomoxis nigromaculatus*)
J 25(2): 285 (feeding biology)
(6): 1199 (low temperature effects on feeding in 3 Ont. localities)
(8): 1651 (plasma protein-bound inorganic iodide)

Crassostrea virginica (*see* Oyster, Atlantic)

Crayfish
J 25(8): 1651 (plasma protein-bound inorganic iodide of *Cambarus*)

Creatine
J 25(12): 2711, 2715 (kinase localization & polymorphism in fish muscle)

Crecy Lake, N.B.
J 25(10): 2011 (steps to increase trout growth rate & yield)

Crisp, Dennis John
J 25(6): 1161 (N American E coast *Hemioniscus balani* and distribution)
(12): 2633 (transplantation of *Balanus balanoides*)

Cristivomer namaycush (*see* Trout, lake)

Cross, Ford A.
J 25(11): 2461 (^{65}Zn in marine crustaceans)

Crustacea (*see also* Crab; Gribble; Lobster; Prawn; Shrimp; *also* subdivisions, e.g. Amphipoda)
J 25(2): 347 (hippolytid & crangonid shrimps from Canadian arctic)
(7): 1311 (pressure effect on respiration of vertically migrating)
CNG 84 (popular description of some NE Pac. Ocean)
T 76 (in tidal Ostrea Lake, N.S.)
S 1260 (adaptation aspects in NW Atl. Ocean)

Cryptomonas curvata & *C. erosa* (*see also* Phytoplankton)
J 25(6): 1229 (in phytoplankton ecology of an Ont. reservoir)

Cryptophyceae
J 25(8): 1603 (fatty acids)
S 1197 (aldolase activity re phylogeny)

CTC (*see* Antibiotics, tetracycline)

Ctenophora
CNG 84 (popular description of some NE Pac. Ocean)
T 55: 20 (identification of B.C.)

Cuerrier, J.-P.
J 25(7): 1511 (Sask. R. lake sturgeon age & growth)

Culture, invertebrate
J 25(8): 1745 (fish muscle homogenate for experimental growth of *Clostridium botulinum*)
B 131(F) (French edition of 1961 original English edition on culture in Canadian Maritime Provinces. *See* Bulletin 164 for complete indexing)
CJG 14 : 35 (Nfld. lobsters)

Cultus Lake, B.C.
B 162 : 180, 240, 255, 314, 387, 400 (re B.C. sockeye salmon studies)

Cumacea
T 25, 35, 59, 60, 73 (in Strait of Georgia benthos biomass)
55 : 99 (identification of B.C.)

Currents (*see also* Oceanography; Tides; Transports, mass)
J 25(5): 1079 (inertial oscillation in NW Atl. at 42°N)
(7): 1485 (longnose dace buoyancy adjustment to velocity)
B 163 : 24 (metering instrumentation)
T 26 (summer, in S Gulf of St. Lawrence)
70 (central B.C. coast)
75 (central subarctic Pac. Ocean region)
85 (free-floating followers)

A 108 (Canadian 1966 ICNAF studies on Atl.)

Cushing, David Henry
J 25(11): 2349 (acoustical estimation of a fish population)

Cusk (*Brosme brosme*)
T 80 (stocks, Gulf of St. Lawrence & N.S. Banks)

Cyanea capillata (*see* Jellyfish)

Cyanocobalamin (*see* Vitamin B group)

Cyanophyta (algae)
J 25(10): 2037 (growth in a thermal stream)
S 1197 (aldolase activity re phylogeny)

Cyclopecten carlottensis (*see* Pecten)

Cyclothone pacifica (*see* Anglemouth, veiled)

Cyclotrichium meunieri (a ciliate)
J 25(8): 1749 (cause of red water in Gulf of Maine)

Cymatogaster aggregata (*see* Perch, shiner)

Cyprinus carpio (*see* Carp)

Cystophora cristata (*see* Seal, hooded)

Cysts (*see also* Disease)
J 25(3): 597 (in yellowtail flounder caused by fungus)

Cytology (*see also* Chromosomes; Histology)
J 25(1): 151 (blood cells of folic acid-deficient coho salmon)
(3): 547 (*Clostridium botulinum* cells & spores)
(7): 1339 (scallop muscle cells)
(10): 2241 (*Amoebophyra* dinoflagellate parasitism of *Gonyaulax* dinoflagellate)
(11): 2269 (arctic Canada bryozoans)
S 1249 (re goldfish spermiation as bioassay for salmon gonadotropin)

D

Dabs (*see* Sanddab)

Dace, blacknose (*Rhinichthys atratulus*)
J 25(8): 1739 (spinal ganglia position re taxonomy)
(10): 2011 (re trout population, Crecy Lake, N.B.)

Dace, longnose (*Rhinichthys cataractae*)
J 25(7): 1485 (buoyancy adjustment re water velocity)

Dace, northern redbelly (*Chrosomus eos*)
J 25(6): 1199 (low temperature effects on feeding in 3 Ont. localities)
(10): 2011 (re trout population, Crecy Lake, N.B.)

Dacnitis truttae (*see* Nematoda)

Daggertooth (*Anotopterus pharao*)
T 11 (in experimental B.C. midwater trawling)

Dahlberg, Michael Lee
J 25(1): 49 (dissolved O_2 & CO_2 on bass & salmon swimming)
(1): 203 (surf smelt W range extension)

Damalichthys vacca (*see* Perch, pile)

Dambergs, Nikolajs
J 25(5): 935 (cod skeletal muscle FAA re gillnet fishing)

Danio, pearl (*Brachydanio albolineatus*)
J 25(8): 1739 (spinal ganglia position re taxonomy)

Danio, spotted (*Brachydanio negrofasciatus*)
J 25(8): 1739 (spinal ganglia position re taxonomy)

Daphnia (*see* Cladocera)

Darter, Iowa (*Etheostoma exile*)
J 25(6): 1199 (low temperature effects on feeding in 3 Ont. localities)

DaSilva, Edgar Joseph
J 25(1): 197 (tropical fish disease micro-organisms)

Dasyatis violacea (*see* Stingray, pelagic)

Davenport, Douglas
T 22 (*G. B. Reed* groundfish cruise No. 67-1)
46 (*G. B. Reed* groundfish cruise No. 67-2)
81 (*G. B. Reed* groundfish cruise No. 68-2)

Day, Donald Stewart
J 25(12): 2665 (species associations off Oregon)

DDT (*see* Insecticides; Pesticides)

Dean, John Mark
J 25(11): 2461 (^{65}Zn in marine crustaceans)

Dean, Margaret Diana
J 25(9): 1923 (*Caligus curtus* Müller, 1785)

Decapoda (*see also* classifications, e.g. Crustacea; *also* common names)
CNG 84 (popular description of some NE Pac. Ocean)
T 25, 35, 59, 60, 73 (in Strait of Georgia benthos biomass)
43 (on Irish moss)
55 : 125 (identification of B.C.)

Delicatessen products (*see* Pastes, fish)

Delisle, Claude Étienne
J 25(9): 1813 (F) (spawning of "giant" smelts, Ottawa Valley)
(12): 2733 (first records of sculpins from Ottawa Valley)

Delphinus delphis (*see* Dolphin, common)

Denaturation (*see* Protein)

Departure Bay, B.C.
S 1223 (seasonal variations in marine benthos feed availability)

Depth (*see also* Hydrography; Limnology; Oceanography)
J 25(12): 2665 (distribution of fishes off Oregon coast)

Dermochelys coriacea coriacea (*see* Turtle, leatherback)

Dermocystidium (*see* Fungus)

Desoxyribose
B 167 : 241 (determination in sea water)

Detritus (*see* Matter, particulate; Sediments)

Development (*see also* Growth; Life history)
J 25(3): 495 (salinity & temperature effects on English sole early)
T 41 (embryonic, of petrale sole)

DeWilde, Mary Anne
J 25(1): 173 (rainbow trout hematological correlations)

Diagramma griseum (*see* Gray skin)

Diaphus theta (*see* Lanternfish, theta)

Diatoms (*see* Bacillariophyceae; Plankton; Phytoplankton)

Diel habits (*see also* Behaviour; Light, reactions to; Salinity, reactions to; Temperature, reactions to)
J 25(6): 1133 (of feeding for 5 freshwater fishes)
(9): 1997 (young prickly sculpin limnetic occurrence)
(10): 2143 (illumination re orientation of eels toward spawning area)

Dieldrin (*see* Insecticides)

Digging
T 15 (fork vs. hydraulic rake for clam)

Dingle, John Reginald
J 25(3): 607 (hemolymph characteristics of *Cancer irroratus, C. borealis,* & *Hyas coarctatus*)
S 1261 (degradation of adenine nucleotides)

Dinoflagellata (*see also Amoebophyra*; *Gonyaulax*)
J 25(10): 2241 (of Sequim Bay, Wash.; cytology)

Dinophyceae
J 25(8): 1603 (fatty acids)

Dips for preserving fish quality
J 25(10): 2071 (tetracyline & ethylenediaminetetracetic acid (EDTA) salts)
T 67, 68 (analysis for EDTA residues in)

Discriminant analysis
T 40 (computer program for)

Disease; Pathology (*see also* Histology; Parasites)
J 25(1): 197 (microorganisms isolated from 12 species of diseased tropical fishes)
(2): 383 (infectious pancreatic necrosis in young trout)
(2): 423 (nocardiosis in brook trout)
(3): 597 (*Ichthyophonus* fungus infection of yellowtail flounder)
(3): 607; (4): 695 (*Gaffkya homari* bacteria effects on lobster & crab hemolymph)
(6): 1247 (kidney-diseased vs. normal sockeye salmon re transaminase activity)
(7): 1521 (*Aeromonas* infection of lamprey & trout)
(11): 2467 (of fungus attack on chinook salmon)
(12): 2643 (furunculosis bacteria distribution in brook trout organs)
B 162 : 91 (of sockeye salmon)
T 83 (bibliography of Atl. salmon diseases)
S 1258 (rainbow trout skin lesions)

Distribution (biological) (*see also* Marking; Migration; Tagging)
J 25(1): 33 of juvenile steelhead vs. cutthroat trouts in SW B.C. steams)
(1): 101 (of white & largescale suckers re hybridization)
(1): 157 (*Mesidotea entomon* in Chignik Lakes, Alaska)
(2): 409, 415 (N American kokanee)
(2): 427 (lobster larvae off Picton, N.S.)
(3): 457 (vertical, of sound-scattering layer fishes)

(3): 485 (of spawning sockeye salmon on Alaska lake beaches)
(5): 943 (*Anonyx* species in N American Atl. & arctic coasts)
(6): 1161 (parasitic copepod *Hemioniscus balani*, E coast of N America)
(6): 1181 (upper Great Lakes benthic environment)
(7): 1423 (E N American *Taeniopteryx* stoneflies)
(9): 1775 (N.S. offshore sand launce)
(11): 2269 (& description of 93 arctic Canada Bryozoa species)
(12): 2665 (depth, of fishes off Oregon coast)
(12): 2527 (brown trout world distribution)
B 162 : 6, 161, 329, 373 (sockeye salmon)
165 : 23 (carp in Canadian waters)
166 : 1, 42 (eels in E Canada)
CJG 15 (Nfld. herring)
T 2 (B.C. marine Mollusca)
31 (Atl. mackerel off Canada)
34 (arrowtooth & spinycheek flounder; rock & flathead sole; Pac. cod)
58 (of Nfld. herring stocks)
74 (vertical & horizontal, of sablefish)
S 1240 (of NE Pac. stranded Cuvier's beaked whales)
A 100 (Man. freshwater fishes)
108 (1966 Canadian ICNAF studies on swordfish & various other Atl. fishes)

Distribution of fatty acids in lipids (*see* Acids, fatty)

Diurnal effects (*see* Behaviour; Diel habits; Light, reaction to)

Dixon Entrance, B.C. (*see* Queen Charlotte Islands region)

Dixon, Gordon Henry
S 1245 (protamin biosynthesis)

Dodimead, Allan John
T 54 (NE Pac. Ocean temperatures & salinities 1965 & 1966)
70 (oceanographic features of central B.C. coast waters)
75 (central subarctic Pac. region oceanographic conditions, winter 1966)

Dog (*Canis familiaris*)
S 1203 (positional distribution of monoenoic fatty acids in mesenteric triglycerides)

Dogfish (European) (*Scyllium canicula*)
J 25(12): 2711 (muscle creatine kinase localization)

Dogfish (*Squalus acanthias*; *S. suckleyi*) (dogfish shark)
J 25(8): 1651 (plasma protein bound inorganic iodide)
(12): 2665 (associations with 60 Oregon coast fish species)
T 7, 11, 19, 22, 30, 46, 56, 62, 81, 89 (in B.C. commercial of experimental trawling)
S 1244 (a corticosteroid 1α-hydroxylase in interrenal tissue)
A 90, 103 (fishery trend along N America Pac. coast)

Dogwinkle, Atlantic (*Thais lapillus*)
J 25(2): 267 (occurrence & retention of thetin derivative from feed)
(9): 1803 (caloric content)

Dolly Varden (*Salvelinus malma*)
B 162 : 243 (predator on young sockeye salmon)

Dolphin (Pacific) (*Coryphaena hippurus*)
J 25(9): 1987 (red & white muscle temperature of recently caught)

Dolphin, common (*Delphinus delphis*)
J 25(12): 2561 (feeding habits from fish otoliths in stomach)

Dolphin, northern right whale (*Lissodelphis borealis*) (right whale dolphin)
J 25(12): 2561 (feeding habits from fish otoliths in stomach)

Dolphin, Pacific spotted (*Stenella graffmani*)
J 25(12): 2561 (feeding habits from fish otoliths in stomach)

Dolphin, Pacific striped (*Lagenorhynchus obliquidens*) (white-sided dolphin)
J 25(12): 2561 (feeding habits from fish otoliths in stomach)

Dolphin, spinner (*Stenella longirostris*)
J 25(12): 2561 (feeding habits from fish otoliths in stomach)

Dolphin, white-sided (*see* Dolphin, Pacific striped)

Dominance (*see* Behaviour; Territorialism)

Donaldson, Edward Mossop
J 25(1): 71 (cortisol in salmonid plasma)
(7): 1465 (metopirone in salmonids)
(7): 1497 (salmon pituitary "prolactin")
S 1249 (spermiation bioassay for gonadotropin)
1259 (C^{14} cortisol in salmon)

Donaldson, Ivan J.
J 25(10): 2233 (tattooing fish)

Donaldson, John Russell
J 25(3): 485 (sockeye spawning)

Doudoroff, Peter
J 25(1): 49 (dissolved O_2 & CO_2 on bass & salmon swimming)

Douraghi-Zadeh, Koshrow
S 1254 (stereoisomerism in fatty acids)

Dragonfish, arrow (*Tactostomus macropus*)
J 25(3): 457 (in N B.C. midwater trawl catches)
T 11, 22 (in B.C. experimental trawling)

Dragonfish, highfin (*Bathophilus flemingi*)
T 11 (in B.C. experimental midwater trawling)

Drags (*see also* Drogues)
J 25(10): 2123 (underwater observation of efficiency for scallops)

Dreamers (*Chaenophryne ochotensis*; *Oneirodes eschrichti*-group; *O. acanthias*)
T 11 (in B.C. experimental midwater trawling)

Drepane punctata (*see* Sicklefish)

Drift (*see* Currents; Drags; Drogues)

Drill, clam (*see* Clam drill)

Drinnan, Roy Ellis
J 25(11): 2521 (microturbellarian in oysters off P.E.I.)
S 1199 (ancient oyster & bay scallop shells from Sable Is.)

Drip
J 25(4): 743 (of frozen trap-caught Atl. cod)
(4): 829 (variations in, on thawing American plaice fillets)
(7): 1475 (in Atl. cod muscle dipped in tripolyphosphate solution)
T 68 (chemical analysis for EDTA residues in)

Drogues (*see also* Floats)
T 26 (in current observations, Gulf of St. Lawrence)
85 (theory & design of)

Drum (*see* Sheepshead)

Dryburgh, James Robert
T 45 (extended tables of the transformation $\varphi = 2 \arcsin \sqrt{X}$)

Dryer, William Raymond
J 25(7): 1377 (Apostle Is. lake trout rehabilitation)

Drying
CJG 15 : 29 (of Nfld. squid)

Duck (*Anas*)
S 1203 (positional distribution of monoenoic fatty acids in triglycerides)

Duff, David Cecil Buchanan
S 1194 (two *Isochrysis galbana* antibacterial products)

Duffy, James Regis
J 25(1): 189 (Atl. fish DDT residues)
S 1210 (butoxyethanol ester of 2,4-D)

Dugal, Louis Charles
J 25(1): 169 (freshwater fish oils & meals pesticide residue)

Dulce (*Rhodymenia palmata*)
S 1239 (sterols)

Duncan, Richard Norman
J 25(10): 2233 (tattooing fish)

Duthie, Hamish Crichton
J 25(6): 1229 (L. Belwood, Ont., phytoplankton ecology)

Dyer, William John
J 25(2): 239 (mackerel muscle nucleotide degradation)
(2): 299 (refrozen cod storage quality)
(4): 817 (redfish muscle hypoxanthine accumulation)
(4): 829 (plaice fillet thaw drip)
(8): 1525 (frozen cod muscle glycogen & phosphorus)

E

Eales, John Geoffrey
J 25(9): 1901 (*Salmo salar* skin & scales)
B 166 (E Canada eel fishery)
T 28 (*Anguilla* bibliography)

Ear (*see* Otoliths; Sound, reactions to)

Earthworms
J 25(1): 205 (records of species collected near Vancouver, B.C.)

Eaton, Catherine Anne
S 1227 (fin whale lipids — fin whale milk)

Eberhardt, Lester Lee
J 25(3): 591 (growth on metabolite retention time)

Ecdysis (*see* Moulting)

Echinoderms (*see also* subclassifications)
J 25(9): 1803 (caloric content of several species)
T 25, 35, 59, 60, 73 (in Strait of Georgia benthos biomass)
43 (on Irish moss)

Echiuroidea
T 25, 35, 59, 60, 73 (in Strait of Georgia benthos biomass)

Echo sounding (*see* Sounding, echo)

Ecology (*see also* aspects of)
J 25(6): 1229 (of phytoplankton in an Ont. reservoir)
(11): 2269 (of arctic Canada Bryozoa)
T 31 (of Canada Atl. coast mackerel)
43 (Irish moss in Nfld. waters)
A 115 (new FRB laboratory, Dartmouth, N.S., for study of marine)

Economics (*see* Fisheries; Management)

Edelhauser, Henry Francis
J 25(5): 863 (trout cornea ultrastructure)

Edmundson, Eldon
J 25(7): 1453 (salmon & trout permanence of station)

Eel, American (*Anguilla rostrata*)
J 25(8): 1591 (rheotaxis re different N.S. steams)
(8): 1739 (spinal ganglia position re taxonomy)
(10): 2011 (re trout population, Crecy Lake, N.B.)
(10): 2143 (orientation toward spawning area)
B 166 (biology; description of E Canada fisheries)
T 28 (bibliography)

Eel, barbel (*Plotosus anguillaris*) (striped catfish)
J 25(1): 197 (microorganisms isolated from diseased)

Eel, conger (*Conger conger*)
J 25(12): 2711 (muscle creatine kinase localization)

Eel, European (*Anguilla anguilla*)
J 25(12): 2715 (muscle creatine kinase localization)
B 166 : 60 (world fishery)
T 28 (bibliography)

Eel, Japanese (*Anguilla japonica*)
B 166 : 60 (world fishery)
T 28 (bibliography)

Eel, snipe (*Borodulina infans*; *B. gilli*; *Serrivomer jesperseni*)
T 11 (in experimental B.C. midwater trawling)

Eelgrass (*Zostera marina*)
CDG 1 (control on oyster beds)
S 1210 (chemical control & its effect on oysters, etc.)
A 109 (same as CDG 1 above)

Eelpout, bigfin (*Aprodon cortezianus*)
J 25(12): 2665 (associations with other fishes off Oregon coast)

Eelpout, black (*Lycodes diapterus*) (blackfin eelpout)
J 25(12): 2665 (associations with other fishes off Oregon coast)

Eelpout, blackbelly (*Lycodopsis pacifica*)
J 25(12): 2665 (associations with other fishes off Oregon coast)

Eelpout, blackfin (*see* Eelpout, black)

Eelpout, longfin (*Bothrocara remigera*)
J 25(12): 2665 (associations with other fishes off Oregon coast)

Eelpout, snakehead (*Embryx crotalina*)
J 25(12): 2665 (associations with other fishes off Oregon coast)

Eelpout, twoline (*Bothrocara brunneum*)
J 25(12): 2665 (associations with other fishes off Oregon coast)

Eelpouts (general)
T 22, 30, 46, 62, 81 (in B.C. experimental trawling)

Effluent (*see* Pollution)

Effort and intensity of fishing (*see* Catches; Fisheries; Trawl)

Eggs, chicken
S 1221 (effect of fishmeal on hatchability)

Eggs, fish (*see also* Fecundity; Spawning)
J 25(3): 495 (temperature & salinity effects on English sole hatchability)
(3): 585 (controlled-environment incubator for small marine)
(8): 1743 (observations on, from butter sole)
(12): 2695 (chilled storage effect on sockeye & pink salmon)
B 162 : 99 (sockeye salmon)
T 19 : 27 (experiments on hatching Pac. cod, English & petrale sole)
41, 89 (petrale sole embryonic development)
89 (flathead sole)

Eglinton, Geoffrey
S 1254 (stereoisomerism in fatty acids)

Eisan, Joanne Sylvia
S 1231 (cod sperm uricolytic enzymes)
1236 (lipid biosynthesis by salmon sperm)
1237 (carbon dioxide fixation by cod spermatozoa)

Electrofishing
B 166 : 23 (for eels)
S 1262 (gear modifications for coho salmon underyearlings)

Electrophoresis; Electropherograms
J 25(3): 607 (of crab hemolymph plasma)

(5): 853 (re glucose metabolism in *Bankia setacea* caecum)
(7): 1317 (of muscle proteins re hybridization inheritance)
(7): 1323 (re lactate dehydrogenase in 3 trout species)
(7): 1517 (separation of fish brain esterases)
(8): 1581 (malic enzyme in fish muscle sarcoplasm)
(8): 1651 (plasma proteins re bound iodide)
(11): 2477 (rockfishes systematics re protein)
(12): 2711, 2715 (fish muscle creatine kinase)
T 31 (Atl. mackerel muscle extracts)
62 : 16 (hemoglobin, of various B.C. groundfish)
S 1204 (re serum transferrin polymorphism in scombroid fishes)
1214 (Atl. oyster hemolymph protein fractions)

Ellerslie Brook, P.E.I.
J 25(2): 209 (effect of artificial pond on brook trout catches)

Ellis, Derek Victor
J 25(8): 1737 (benthic investigations computer programs)
T 25, 35, 59, 60, 73 (quantitative benthic investigations)

Elson, Paul Frederick
T 6 (N.B. forest spraying damage to salmon fisheries)
A 83 (criteria for pesticide residues)

Elver (*see* Eel, American)

Embassichthys bathybius (*see* Sole, deepsea)

Embiotoca lateralis (*see* Seaperch, striped)

Embryology (*see* Eggs, fish; Larvae)

Embryx crotalina (*see* Eelpout, snakehead)

Endocrinology (*see also* Hormones; Steroids)
R 1965–1966: 31, 80 (programs of Fisheries Research Board)

Engraulis mordax mordax (*see* Anchovy northern)

Ennis, Gerald Peter
J 25(12): 2723 (lobsters from 95 fath off Nfld.)
(12): 2729 (staghorn sculpin in Nfld. waters)

Enophrys bison (*see* Sculpin, buffalo)

Ensilage
A 98 (from Pac. herring re Atl. herring use)

Entosphenus (*see Lampetra*)

Enumeration (*see* Counting)

Enzymes
J 25(4): 615 (fish brain acetylcholinesterase properties)
(6): 1247 (transaminases distribution & action in Pac. salmon tissues)
(7): 1323 (lactate dehydrogenase in 3 trout species)
(7): 1517 (fish brain esterases electrophoretic separation)
(8): 1539 (postmortem muscle glycogen & starch degrading)
(8): 1571 (organophosphatases in fish liver)
(8): 1581 (malic: 2 forms in fish skeletal muscle sarcoplasm)
(12): 2711, 2715 (fish muscle creatine kinase)
R 1965–1966: 82 (Board Vancouver Laboratory summary of investigations)
T 31 (re Atl. mackerel biochemistry)
S 1197 (aldolase activity of various marine planktonic algae)
1229 (oxidation of choline by *Achromobacter*)
1231 (uricolytic in Atl. cod sperm)
1244 (corticosteroid 1α-hydroxylase in elasmobranch interrenals)
1248 (phospholipase C from a marine planktonic alga)
1250 (pancreatic lipase substrate specificity)
1258 (proteinase of proteolytic pseudomonad from trout skin lesions)
A 98 (proteolytic, for herring digestion to by-products)

Eopsetta jordani (*see* Sole, petrale)

Epinephelus striatus (*see* Grouper, Nassau)

Eptatretus deani (*see* Hagfish, black)

Eptatretus stoutii (*see* Hagfish, Pacific)

Equipment (*see* Apparatus)

Erie, Lake (*see* Great Lakes)

Esox americanus vermiculatus (*see* Pickerel, grass)

Esox lucius (*see* Pike, northern)

Esox masquinongy (*see* Maskinonge)

Esters (*see also* Acids, fatty)
J 25(4): 615; (7): 1517 (fish brain esterases)
S 1222 (molar responses of some polyfunctional metabolic acid methyl)

Estuary
S 1257 (nets for trapping Atl. salmon)

Etheostoma exile (*see* Darter, Iowa)

Ethylenediaminetetraacetic acid (EDTA) and salts
J 25(8): 1753; (10): 2071 (as bactericide & bacteriostat)
T 67, 68 (chemical analysis for residues)

Eualus (hippolytid shrimps)
J 25(2): 347 (Queen Elizabeth Is., Canadian arctic)
S 1260 (adaptation re other shrimps in NW Atl.)

Eubalaena glacialis (*see* Whale, right)

Eubothrium (*see* Tapeworm)

Eucalia inconstans (*see* Stickleback, brook)

Eulachon (*Thaleichthys pacificus*)
T 11, 22, 30, 62, 81 (in B.C. experimental trawling)

Euphausiacea
J 25(5): 1071 (*Meganyctiphanes norvegica* larvae occurrence off W Greenland)
(7): 1311 (pressure effect on respiration of vertically migrating *Euphausia pacifica* & *Thysanoëssa spinifera*)
(11): 2461 (tissue distribution of natural ^{65}Zn in *E. pacifica*)
CNG 84 (popular description of some NE Pac. Ocean)
T 55 : 117 (identification of B.C.)

Euthynnus lineatus (*see* Skipjack, black)

Euthynnus pelamis (*see* Tuna, skipjack)

Eutrophy (*see also* Limnology)
J 25(1): 81 (artificial vertical circulation effects in lakes)

Everest, Fred Henry
J 25(7): 1453 (salmon & trout permanence of station)

Everhart, Watson Harry
J 25(1): 1 (hatchery-reared & wild salmon behavior)

Evolution (*see* Phylogeny)

Excreta
J 25(1): 25 (of M.S. 222 anesthetic in rainbow trout urine)

Exercise (*see* Activity; Stress)

Exoskeleton
J 25(11): 2461 (accumulation of natural ^{65}Zn in crustacean)

Exploitation
J 25(2): 209 (of brook trout angling in Ellerslie Brook, P.E.I.)
(4): 667 (re species succession in Great Lakes)
(5): 1291 (age at given fishing mortality: mathematics of)
(7): 1347 (mature walleye in Nipigon Bay region, Ont.)
B 162 : 49 (commercial trends: sockeye salmon)
A 105 (effect of modern fishing gear on B.C. herring stocks)

Exploration; Prospecting (*see also* Surveys)
CNG 85 (for B.C. shrimps)
T 18 (for shrimp in Gulf of Alaska & Bering Sea, 1957–64)
61 (for shrimps off B.C., 1966 & 1967)
A 104 (based on CNG 85 above)
108 : 21 (for sea & Iceland scallops)

Eye (*see also* Light, reactions to)
J 25(2): 373 (bluegill retinomotor rhythms)
(5): 863 (cornea ultrastructure of 3 trout species)
(9): 2001(F) (walleye & sauger retinal structure re habitat turbidity)
(11): 2461 (accumulation of natural ^{65}Zn in crustacean)
(11): 2477 (lens protein electrophoresis of 20 rockfish species re systematics)

F

Fager, Edward William
J 25(7): 1405 (recurrent species groups in Gulf of Guinea)

Fagerlund, Ulf Henrik Mathias
J 25(1): 71 (cortisol in salmonid plasma)
(7): 1465 (metopirone in salmonids)
S 1259 (C^{14} cortisol in salmon)

Fat (*see* Acids, fatty; Condition; Oils and fats; Lipids; Phospholipids; Triglycerides)

Fatigue (*see* Activity; Stress)

Fatness; Fat content (condition) (*see* Composition, chemical; Condition; Oils and fats)

Fatty acids (*see* Acids, fatty)

Fatty Basin, Vancouver Is., B.C.
T 44 (progress report on lobster transplant)
A 93 (site of lobster transplant experiment)

Fauna (*see* Benthos; Biomass; Lists; *also* types and names of)

Fecundity (*see also* Reproduction)
J 25(1): 157 (*Mesidotea entomon* in Chignik Lakes, Alaska)
(6): 1299 (estimation of winter flounder)
(9): 1813(F) ("giant" smelts of Heney L., Que.)
(10): 2225 (white perch)
B 162 : 99, 123 (sockeye salmon)
165 : 14 (carp)

Feed; Feeding habits; Stomach contents (*see also* Feedstuff; Predation)
J 25(1): 1 (feeding behaviour of hatchery vs. wild Atl. salmon parr in aquaria)
(1): 151 (folic acid deficient diet effect on coho salmon blood)
(1): 157 (*Mesidotea entomon* in Chignik Lakes, Alaska)
(2): 267 (of filter-feeding animals re thetin derivative retention)
(2): 285 (feeding biology of black crappie)
(2): 347 (stomach contents of Canadian arctic shrimps)
(2): 393 (effect of light on jack mackerel)
(3): 599 (chum salmon fry feeding in B.C. fresh water)
(4): 717 (statistical analysis of ration re growth of European plaice)
(4): 807 (of buffalo sculpin)
(4): 825 (feeding behaviour of 3 NE Pac. oceanic fishes)
(5): 903 (swordfish in NW Atl.)
(5): 1085 (of 4 salmon species & steelhead trout in NE Pac. Ocean)
(6): 1133 (of 5 freshwater fish species)
(6): 1199 (low temperature effect on Great Lakes fishes)
(9): 1775 (importance to predator species)
(12): 2561 (habits of cetaceans from fish otoliths in stomachs)
(12): 2589 (of Fraser R. white sturgeon)
B 162 : 166, 234, 254, 340 (young & mature sockeye salmon)
165 : 15 (carp)
T 74 (of sablefish)
S 1206 (of salmon from Labrador Sea & off W Greenland)
1223 (seasonal availability variations for coastal benthos)
1228 (of fish, whales, & seals, re isoprenoid fatty acids of their oils)
A 115 (new FRB laboratory, Dartmouth, N.S., marine ecology research)

Feedstuff (*see also* Fishmeal)
T 7, 19, 56, 89 (landings from B.C. trawl fisheries)
A 91 (utilization of B.C. fishes for animal food; list of 41 species found in landings)

Fenderson, Owen Charles
J 25(1): 1 (hatchery-reared & wild salmon behavior)

Fertility (*see* Eggs; Fecundity; Matter, particulate; Phytoplankton; Plankton; Productivity, primary; Reproduction; Sperm)

Fertilizer
J 25(10): 2011 (for increasing trout growth rate & yield in lake)
CJG 14 : 30 (Nfld. landings of capelin for)
T 76 (pre-fertilization benthic survey, Ostrea Lake, N.S.)

Fibre, crude
B 167: 235 (determination in sea water)

Fillets
J 25(2): 299 (storage quality of refrozen Atl. cod)
(3): 605 (ultrasonic test for quality of frozen & thawed whitefish)
(4): 733 (trap-caught Nfld. cod: freezing effects on quality)
(4): 817 (rapid hypoxanthine accumulation in iced redfish)
(4): 829 (thaw-drip in American plaice)
(5): 921 (nonbacterial trimethylamine production in frozen Atl. cod)
(8): 1753; (10) 2071 (preservation by ethylenediaminetetraacetic acid salts)
(12): 2749 (incidence of codworm in Atl. cod)
T 67, 68 (analysis for residues of EDTA preservatives)

Fingerlings (*see* names of adult fishes, e.g. Trout; Salmon)

Fins (*see also* Marking)
J 25(4): 813 (sexual dimorphism in trout anal)
(7): 1511 (rays for lake sturgeon ageing)
(12): 2589 (rays for white sturgeon ageing)

Fish Lake, Ont.
J 25(6): 1199 (water temperature effect on fish feeding)

Fish protein concentrate (FPC) (*see* Protein concentrate)

Fisheries (*see also* Catches; *also* names of commercial fishes, shellfish, etc.)
J 25(4): 667 (exploitation re species succession in Great Lakes)
(12): 2589 (Fraser R. white sturgeon)
B 162 : 43 (sockeye salmon)

Abbreviations: J — Journal; B — Bulletin; AR — Annual Report; R — Review; *Circular series*: CDG — Dartmouth; CHN — Halifax; CJG — St. John's; CNG, CNS — Nanaimo; CSG — St. Andrews; CVG — Vancouver; T — Technical Reports; MSP — Miscellaneous Special Publications; S — Studies; A — Interpretive Articles.

165 : 39 (carp in Canada: history, present, and potential)
166 (eel, of E Canada)
T 7, 12, 19, 23, 56, 89 (B.C. commercial trawl)
31 (Atl. mackerel)
33 (Great Slave L. winter fishery production re number of fishermen)
S 1209 (effect of offshore fishing on inshore Labrador cod fishery)
A 90, 103 (trends in Pac. coast marine)
94, 95, 96 (Atl. herring)
99 (production from NW Atl.)

Fisheries Research Board of Canada
AR 1967 (Annual Report: Board members; Executive Committee members; Officers; establishments & directors; Chairman's review; research programs in 1967; research highlights; expenditures by areas & disciplines, 1967–68 (in English & French)
R 1965–1966 (Biennial Review: Board members; organization; reviews of investigations by establishments, with lists of scientific staffs; list of 1965 & 1966 Board publications & reports)
MSP 10 (outline of origin; organization; programs; co-operation with other bodies; 1967–68 operating costs & distribution; list of establishments)
11 (place in Canada's scientific development 1968–1978)
A 77 (brief review of 1964–65 operating expenditures re previous 12 years; also of 1964–65 research on fisheries products)

Fishes, lists of (*see* Lists of fishes)

Fishes, tropical
J 25(1): 197 (microorganisms isolated from 12 species of diseased)
(7): 1405 (recurrent group analysis of species assemblages, Gulf of Guinea)

Fishing methods (*see also* Apparatus; Fisheries; *also* names of types of gear)
B 165 : 60, 76 (sports & commercial, for carp)
166 : 7, 62 (eels in E Canada)
T 13 (B.C. groundfish)
31 (Atl. mackerel)

Fishmeal (*see also* Feedstuff; Reduction)
J 25(1): 169 (pesticide residues in freshwater fish)
CVG 39 (pilot plant for research)
40 (antioxidants for spontaneous heating control in Canadian herring meals)
S 1221 (B.C. herring & Atl. whitefish meals re chicken egg hatchability)
A 85 (nutrient composition of freshwater, as poultry feed)
97 (nutrient value of Atl. & Pac. herring)
98 (& stickwater concentrates from Atl. & Pac. herring)
112 (same as CVG 39 above)

Fitch, John Edgar
J25(12): 2561 (fish otoliths in cetacean stomachs)

Fitz-Earle, Malcolm
J 25(2): 255 (Heming L., Man., fish stain marking)

Flagellata (*see* Dinoflagellata)

Flatfishes (*see* Groundfish; *also* names of species)

Flavour (*see also* Quality of fishery products)
A 80 (nature & significance in sea foods)

Fleming, Allister Melville
CJG 14 (1966 Nfld. groundfish landings)
15 (1967 Nfld. groundfish landings)

Flemming, Carol
S 1214 (hemagglutinins from oyster hemolymph)

Flesh (*see* Browning of flesh; Fillets; Muscle; Protein; Quality of fishery products)

Floats (*see also* Drogues)
T 85 (theory & designs of free-floating current followers)

Flora, aquatic (*see* Algae; Benthos; Biomass; Production, primary; Seaweeds; *also* types and names of)

Flounder, arrowtooth (*Atheresthes stomias*) (Pacific turbot)
J 25(3): 457 (in N B.C. midwater trawl catches)
(12): 2665 (associations with other fishes off Oregon coast)
T 7, 11, 16, 19, 22, 30, 46, 56, 81, 89 (in B.C. experimental or commercial trawling)
34 (distribution, stocks, population, synonymy, systematics)
81 (parasitic copepods of)
A 91 (1951–66 B.C. catches for mink feed)

Flounder, blackback (*see* Flounder, winter)

Flounder, starry (*Platichthys stellatus*)
J 25(8): 1539 (postmortem muscle glycogen & starch degradation)
(8): 1651 (plasma protein-bound inorganic iodide)
(12): 2665 (associations with other fishes off Oregon coast)
T 7, 11, 19, 56, 62, 89 (in B.C. experimental or commercial trawling)
A 91 (1951–66 B.C. catches for mink feed)

Flounder, winter (*Pseudopleuronectes americanus*) (blackback flounder)
J 25(5): 1061 (fatty acids of commercial liver oil)
(6): 1299 (fecundity estimate)
T 80 (stocks, Gulf of St. Lawrence & N.S. Banks)
A 108 (1966 Canadian ICNAF studies: commercial catches)

Flounder, witch (*Glyptocephalus cynoglossus*) (graysole; witch)
CJG 14 (Nfld. landings 1966)
15 (Nfld. landings, 1952–67)
S 1212 (age determination from otoliths)
1213 (re weight relations)
T 80 (stocks, Gulf of St. Lawrence & N.S. Banks)
A 108 (1966 Canadian ICNAF studies: commercial catches; larvae)

Flounder, yellowfin (*see* Sole, yellowfin)

Flounder, yellowtail (*Limanda ferruginea*)
J 25(3): 597 (*Ichthyophonus* fungus infection)
CJG 14 (Nfld. commercial landings, 1966)
15 (Nfld. landings, 1962–67)
S 1213 (re weight relations)
T 80 (stocks, Gulf of St. Lawrence & N.S. Banks)
A 108 (1966 Canadian ICNAF studies: commercial catches; meristics data re stocks; parasite)

Flounders (in general) (*see also* Flatfishes; Groundfish)
J 25(5): 1061 (fatty acid composition of commercial Atl. "flounder" liver oil)
T 68 (fillet analysis for ethylenediaminetetraacetic acid preservative content)
A 99 (fishery yields in NW Atl., 1952–64)

Flour, fish (*see* Protein concentrate)

Flow (*see* Currents; Oceanography; Tides; Transport, mass)

Foerster, Russel Earl
B 162 (sockeye salmon)

Folic acid
J 25(1): 151 (deficiency effect on coho salmon blood)

Food of animals (*see* Feed; Feedstuff)

Foot (of molluscs) (*see* Podium)

Foraminifera
T 60 (in Strait of Georgia benthos biomass)

Forecast
A 99 (fisheries production from NW Atl.)

Forest spraying by insecticides (*see* Insecticides)

Fork
T 15 (vs. hydraulic rake for B.C. clams)

Forrester, Clifton Roger
J 25(3): 495 (salinity & temperature on English sole)
T 19 (1966 B.C. trawl fishery)
41 (petrale sole embryonic development)
89 (B.C. trawl fishery, 1967)
A 91 (fish for animal food in B.C.)

Forsythe, Michael George
T 4 (1965 NW Miramichi R., N.B., smolt run)

Fowler, Laurie Garth
J 25(3): 611 (juvenile salmonid skin pallor by guanidine compounds)

Fowler, Scott Wellington
J 25(11): 2461 (^{65}Zn in marine crustaceans)

Fox, Alfred Carter
J 25(8): 1741 (water core plankton sampler)

Fraser, Doris Isabel
(2): 239 (mackerel muscle nucleotide degradation)
(2): 299 (refrozen cod storage quality)
(4): 817 (redfish muscle hypoxanthine accumulation)
(4): 829 (plaice fillet thaw drip)
(8): 1525 (frozen cod muscle glycogen & phosphorus)
S 1261 (degradation of adenine nucleotides)

Fraser River, B.C. (*see also* Salmon)
J 25(12): 2589 (age, growth, feed, & yield of white sturgeon)
B 162 : 72 (sockeye salmon spawning areas)
S 1230 (spawning populations of sockeye & other salmons)

FRB (Nanaimo)
A 86 (problems raised by the protocol — ICNAF)

FRB (St. Andrews
A 111 (anti-pollution & Atl. salmon)

Freeman, Harry Cleveland
J 25(2): 363 (Atl. salmon sperm subzero preservation)
S 1205 (1α-hydroxycorticosterone activity)

Freese, Manfred
J 25(3): 605 (tissue ultrasound backscatter)

Abbreviations: J — Journal; B — Bulletin; AR — Annual Report; R — Review; *Circular series*: CDG — Dartmouth; CHN — Halifax; CJG — St. John's; CNG, CNS — Nanaimo; CSG — St. Andrews; CVG — Vancouver; T — Technical Reports; MSP — Miscellaneous Special Publications; S — Studies; A — Interpretive Articles.

Freezing (*see also* Refrigeration; Thawing)
J 25(2): 299 (rigor effect on processing Atl. cod)
(3): 605 (ultrasonic effects as quality test for flesh after)
(4): 733 (effect on trap-caught Atl. cod re prior handling)
(12): 2623 (very low temperature preservation of Atl. cod sperm)
A 79 (re protein denaturation & "browning")

Freitas, Yvonne Mae
J 25(1): 197 (tropical fish disease microorganisms)

Freshwater fish products (*see also* names of freshwater fishes)
J 25(1): 169 (pesticide residues in oils & meals)
(3): 605 (ultrasonic backscatter as quality test for frozen whitefish)
A 85 (nutrient composition of meals as poultry feed)

Frog (*Rana pipiens*)
J 25(8): 1651 (plasma protein-bound inorganic iodide)
S 1226 (fatty acids positional distribution in triglycerides)

Fry (*see* names of adult fishes, e.g., Trout; Salmon)

Fry, Frederick Ernest Joseph
J 25(11): 2257 (L. Manitou, Ont., marked lake trout survival)

Fujihara, Masaaki Paul
J 25(11): 2467 (chinook mortality re *Dermocystidium*)

Fulton, John Douglas
CNG 84 (zooplankton of NE Pac. Ocean)
T 37 (zooplankton net for coastal observations)
55 (manual for identification of B.C. marine zooplankton)

Fundulus diaphanus (*see* Killifish, banded)

Fundulus heteroclitus (*see* Mummichog)

Fundy, Bay of
J 25(6): 1097 (natural tidal oscillations)
(12): 2721 (first Greenland halibut record)
T 57 (length & age distribution of herring)

Fungicides
J 25(11): 2467 (for *Dermocystidium* on salmons)

Fungus
J 25(3): 597 (*Ichthyophonus* infection of yellowtail flounder)
(11): 2467 (*Dermocystidium* cause of chinook salmon mortality)
B 162 : 92 (*Saprolegnia parasitica* infection of sockeye salmon)

Fur-bearing animals (*see* Mink; Seal)

Furunculosis
J 25(7): 1521 (in lampreys from *Aeromonas* species)
(12): 2643 (experimental brook trout plantings from infected stock)
B 162 : 93 (in sockeye salmon from *Aeromonas salmonicida*)

G

Gadus callarias (*see* Codling)

Gadus macrocephalus (*see* Cod, Pacific)

Gadus morhua (*see* Cod, Atlantic)

Gaffkya homari (pathogenic bacteria)
J 25(3): 607 (comparative effects on lobster & crabs hemolymphs)
(4): 695 (interaction with lobster defense mechanism)
(4): 795 (pathogenicity for rock crab)
T 44 (re transplant of lobsters to B.C.)

Gakstatter, Jack Henry
J 25(9): 1797 (^{14}C-aldrin on ^{14}C-dieldrin in goldfish)

Galeorhinus galeus (*see* Tope)

Galeorhinus zyopterus (*see* Shark, soupfin)

Gall bladder (*see* Bladder, gall)

Gallus domesticus (*see* Chicken)

Gardner, Linda Joanne
J 25(8): 1555 (starvation re rainbow trout free fatty acids)

Garnett, Donald Geoffrey
J 25(3): 597 (yellowtail flounder *Ichthyophonus* infection)

Garside, Edward Thomas
J 25(12): 2717 (cyprinodontids upper lethal temperatures)

Gasterosteus aculeatus (*see* Stickleback, threespine (freshwater))

Gasterosteus wheatlandi (*see* Stickleback, blackspotted)

Gastropoda (*see also* subclassifications and names of species)
T 2 (distributional checklist & bibliography of B.C. marine)
25, 35, 59, 60, 73 (in Strait of Georgia benthos biomass)

43 (on Irish moss)
76 (in tidal Ostrea Lake, N.S.)

Gear, fishery (*see* Apparatus; Fishing methods; Net, gill; Nets; Selectivity of fishing gear; Trawl; etc.)

Gebhardt, Gary Alan
J 25(11): 2519 (fish-marking technique)

Gee, John Henry
J 25(7): 1485 (buoyancy adjustment by longnose dace)

Geen, Glen Howard
J 25(10): 2219 (C^{14} activity on storage)

Geiger, Stephen Ralph
J 25(8): 1637 (NE Greenland amphipods)

Genital system (*see* Eggs, fish; Hormones; Milt; Ovary; Testes)

Geology
J 25(11): 2327 (Fe, Mn, & Ti in St. Lawrence R. estuary glacial marine sediments)

Georgia, Strait of (*see also* Oceanography, B.C. coast; Trawl)
T 25, 35, 59, 60, 73 (quantitative benthic investigations in Satellite Channel)

Ghelardi, Raymond Joseph
T 44 (Fatty Basin lobster introductions 1965 & 1966 report)
A 93 (Atl. lobsters in B.C. waters)

Gilgan, Michael Wilson
S 1224 (conversion of androstenedione to testosterone by lobster tissues)

Gill, Carl Alan
J 25(1): 33 (S B.C. trout distribution)

Gill, Charles David
J 25(4): 825 (three oceanic fishes' feeding behavior)

Gill net and netting (*see* Net, gill; Nets)

Gill; Gillrakers (*see also* Net, gill; Respiration; Selectivity of fishing gear)
J 25(2): 415 (gillraker number variation in N American kokanee)
(4): 695 (*Gaffkya homari* infection of lobster)
(9): 1797 (dieldrin accumulation in goldfish, after aldrin ingestion)
(11): 2467 (*Dermocystidium* fungus infection of chinook salmon)
(11): 2521 (microturbellarian associated with Atl. oyster)

Ginglymostoma cirratum (*see* Shark, nurse)

Glenn, Clifford Lawrence
J 25(7): 1505 (measuring walleye stomach contents by "wet" weight)

Globicephala melaena (*see* Whale, pilot)

Glucosamine (*see* Chitin)

Glucose (*see also* Sugars)
J 25(5): 853 (metabolism in marine wood borer caecum)

Glycerides (*see* Triglycerides; *also* Acids, fatty; Lipids; Oils and fats)

Glycogen; Glycolysis (*see also* Carbohydrates)
J 25(4): 738 (before & after freezing trap-caught Atl. cod)
(5): 837 (of exercised Atl. cod muscle)
(8): 1525 (quantitative extraction from frozen Atl. cod muscle)
(8): 1539 (postmortem degradation in fish muscle)

Glyoxalate
S 1236, 1237 (metabolism by Atl. salmon & cod sperm)

Glyptocephalus cynoglossus (*see* Flounder, witch)

Glyptocephalus zachirus (*see* Sole, rex)

Godfrey, Harold
J 25(9): 1971 (ageing chinook salmon from scales)

Goldeye (*Hiodon alosoides*)
J 25(12): 2603 (respiration)

Goldfish (*Carassius auratus*)
J 25 (7): 1333 (marking by feeding strontium-rich diet)
(7): 1497 (hypophysectomy effect and relief)
(8): 1689 (respiratory quotient)
(9): 1797 (dieldrin residues in tissues after aldrin ingestion)
S 1226 (fatty acids positional distribution in fat triglycerides)
1249 (spermiation as bioassay for salmon gonadotropin)

Goldsack, Douglas Eugene
S 1232 (protein polypeptide chains)
1253 (virus structure & subunit amino acid composition)

Gonadotropin (*see* Hormones; Sperm)

Gonads (*see* Ovary; Testes)

Gonatus fabricii (*see* Squid, arctic)

Gonyaulax species (protozoan dinoflagellates)
J 25(10): 2241 (*Amoebophyra* dinoflagellate parasitic on *G. catenella*)

Gosselin-Rey, Cécile Françoise
J 25(12): 2711 (fish creatine kinase in electrophoretic patterns)
(12): 2715 (carp muscle creatine kinase)

Gould, Edith
J 25(8): 1581 (fish skeletal muscle malic enzyme)

Graham, Joseph James
J 25(6): 1169 (sampling larval herring with buoyed & anchored nets)

Grampus orca (*see* Whale, killer (Atlantic))

Grand Bank, off Nfld. (*see also* International Commission for the Northwest Atlantic Fisheries)
S 1207 (diurnal variation in American plaice catches)

Grayling, arctic (*Thymallus arcticus*)
J 25(8): 1651 (plasma protein-bound inorganic iodide)
(8): 1667 (cytotaxonomic relation to other Great Lakes coregonids)

Grayskin (*Diagramma griseum*)
J 25(1): 197 (microorganisms isolated from diseased)

Graysole (*see* Flounder, witch)

Great Lakes (*see also* names of individual Great Lakes)
J 25(4): 667 (species succession & fishery exploitation)
(6): 1181 (benthic environment subdivisions of upper)
(6): 1199 (low temperature effect on fish feeding)
(7): 1521 (sea & brook lampreys infection by *Aeromonas*)
(8): 1667 (cytotaxonomic relations of coregonids)
A 106 (history & further possibilities of transplanting *Oncorhynchus* into)

Great Slave Lake, N.W.T.
T 33 (number of fishermen re winter fishery production)

Greeneye, longnose (*Parasudis truculentus*)
J 25(2): 421 (range extension N to N.S.; morphology)

Greenland
J 25(5): 943 (*Anonyx* species distribution off)
(5): 1071 (*Meganyctiphanes norvegica* larvae off W)
(8): 1637 (habitat of 9 pelagic amphipod species in NE slope waters)
S 1206 (characteristics of salmon taken off W)
1217 (revised growth rate estimates for salmon off)
1218 (re Canadian Maritimes salmon tagging results)

Greenling, kelp (*Hexagrammos decagrammus*)
J 25(8): 1651 (plasma protein-bound inorganic iodide)

Greenling, painted (*Oxylebius pictus*)
T 56 (in commercial B.C. trawling)

Greenling, whitespotted (*Hexagrammos stelleri*)
J 25(8): 1651 (plasma protein-bound inorganic iodide)
T 11, 62 (in B.C. experimental trawling)

Greenwell, Marshall
J 25(4): 829 (plaice fillet thaw drip)

Greer, Galen Leroy
J 25(11): 2321 (DDT degradation in Atl. salmon)

Grey (*see* Gray)

Gribble (*Limnoria lignorum*)
CSG 53 (new treatment to combat)
A 114 (same as CSG 53 above)

Grilse (*see* Salmon, Atlantic)

Gring, David Michael
J 25(2): 373 (bluegill retinomotor rhythms)

Grinols, Richard Byron
J 25(4): 825 (three oceanic fishes, feeding behavior)

Gronlund, William Dixon
J 25(3): 473 (salmon blood lactate after exercise)

Groundfish (Atlantic) (*see also* International Commission for the Northwest Atlantic Fisheries; *also* names of commercial species)
CJG 14, 15 (Nfld. surveys & landings, 1966, 1967)
A 108 (1966 Canadian ICNAF studies)

Groundfish (Pacific) (*see also* names of species)
A 90, 103 (fishery trends along N American Pac. coast)
T 7, 11, 12, 16, 19, 22, 23, 30, 46, 56, 62, 81, 89 (catches, catch effort, investigations, etc., in commercial or experimental trawling off B.C.)

Group analysis (*see* Species group analysis and assemblages)

Grouper, black (*Mycteroperca bonaci*)
J 25(7): 1441 (attraction with pulsed low-frequency sound)

Grouper, Nassau (*Epinephelus striatus*)
J 25(7): 1441 (attraction with pulsed low-frequency sound)

Grouper, yellowfin (*Mycteroperca venenosa*)
J 25(7): 1441 (attraction with pulsed low-frequency sound)

Groves, Alan Brown
J 25(5): 867 (olfaction/vision in spawning site choice)

Growth (*see also* Age; Development; Size)
J 25(1): 157 (*Mesidotea entomon* in Chignik Lakes, Alaska)
(3): 547 (& spore development of *Clostridium botulinum*)
(3): 591 (mathematics of growth effect on radionuclide retention time)
(4): 657 (& age of Ungava round whitefish)
(4): 717 (re ration of European plaice)
(6): 1303 (polemic on mathematical treatment of asymptotic)
(7): 1511 (& age of Sask. R. delta sturgeon)
(8): 1621 (effect of insecticide on cockle clam)
(9): 1775 (N.S. offshore sand launce)
(9): 1831 (F) (& age of 4 Que. lakes maskinonge)
(10): 2011 (lake fertilization to increase trout growth rate & yield)
(10): 2091 (of lake whitefish, Lac la Ronge, Sask.)
(11): 2443 (DDT insecticide effect on brook trout)
(12): 2589 (Fraser R. white sturgeon)
B 162 (sockeye salmon; 271: in lakes; 353: in sea)
165 : 12 (carp)
S 1198 (N compounds governing *Hemiselmis virescens* phototrophic)
1212 (computed rate for witch flounders)
1217 (revised rate estimates for salmon returning from Greenland to N.B.)
1255 (NW Atl. capelin)
T 27 (Strait of Belle Isle summer cod)
31 (Atl. mackerel)
36 (rate comparisons for NE Pac. rock sole)
A 108 (Canadian 1966 ICNAF studies on various Atl. fishes)

Gruchy, Charles George
J 25(4): 813 (brown trout anal fin sexual dimorphism)

Guanidine derivatives
J 25(3): 611 (induce skin pallor in young salmonids)

Guanine (*see* Purines)

Guiding
B 162 : 18, 26, 298 (factors in migratory young & mature sockeye salmon)

Guilbaut, Raymond
J 25(5): 935 (cod skeletal muscle FAA re gillnet fishing)

Guinea, Gulf of
J 25(7): 1405 (recurrent group analysis of demersal fish species assemblages)

Gulfs (*see* Alaska; Guinea, Gulf of; St. Lawrence, Gulf of)

Gulls
B 162 : 85 (sockeye salmon predators)
S 1226 (fatty acids positional distribution in herring gull (*Larus argentatus*) and gray gull (*L. marinus* triglycerides)

Gunnel, penpoint (*Apodichthys flavidus*)
J 25(2): 335 (host to new parasitic chondracanthid copepod)
(8): 1651 (plasma protein-bound inorganic iodide)

Gurnet (*Trigla gurnardus*)
J 25(12): 2711 (muscle creatine kinase localization)

Gymnocanthus tricuspis (*see* Sculpin, staghorn)

Gyrocotyle (*see* Tapeworms)

H

Habits (*see* Behaviour; Diel habits; Territorialism)

Hadaway, William Charles
J 25(11): 2477 (protein electrophoresis re rockfish systematics)

Haddock (*Melanogrammus aeglefinus*)
J 25(4): 639 (catalysis of flesh oxidative rancidity by metal ions)
(8): 1581 (malic enzymes in skeletal muscle sarcoplasm)
(10): 2071 (fillet preservation by ethylenediaminetetraacetic acid salts)
CJG 14 (10: 1966 research; 44: commercial landings, 1966)
15 (35: new brood on Nfld. Bank; 39: commercial landings, 1952–67)
T 68 (fillets analysis for EDTA preservative content)
80 (stocks, Gulf of St. Lawrence & N.S. Banks)

A 99 (fishery yields, 1952–64)
108 (1966 Canadian ICNAF studies: commercial catches; year-classes)

Haemulon album (*see* Margate)

Hager, Stephen Warner
J 25(12): 2739 (NE Pac. phosphate & silicate distribution)

Hagfish, black (*Eptatretus deani*)
J 25(12): 2665 (associations with other Oregon coast fishes)

Hagfish, Pacific (*Eptatretus stoutii*)
J 25(12): 2665 (associations with other Oregon coast fishes)
T 22, 81 (in B.C. experimental groundfish trawling)

Hair
S 1220 (re Pinnipedia phylogeny)

Hake (Atlantic) (*Urophycis* species)
J 25(11): 2349 (direct population estimate by echo sounding)
CJG 14 (Nfld. landings, 1966)
15 (Nfld. landings, 1952–67)
A 108 (1966 Canadian ICNAF studies: age from otoliths)

Hake, Pacific (*Merluccius productus*)
T 7, 11, 22, 30, 46, 56, 81 (in experimental or commercial B.C. trawling)
A 90, 103 (fishery trend along N America coast)
91 (observed in B.C. catches of fish for mink feed)

Hake, silver (*Merluccius bilinearis*)
J 25(5): 907 (as swordfish feed in NW Atl.)
T 80 (stocks, Gulf of St. Lawrence & N.S. Banks)
A 99 (fishery yields, 1952–64)

Hake, white (*Urophycis tenuis*)
T 80 (stocks, Gulf of St. Lawrence & N.S. Banks)

Halargyreus johnsonii (a morid fish)
J 25(5): 877 (speciation & meristic characters)

Halibut, Atlantic (*Hippoglossus hippoglossus*)
CJG 14 (Nfld. landings, 1966)
15 (Nfld. landings, 1952–67)
T 80 (stocks, Gulf of St. Lawrence & N.S. Banks)
S 1211 (changes in ICNAF Subareas 3 & 4 fishery, 1954–64)
A 108 (1966 Canadian ICNAF studies: commercial catches)

Halibut, Greenland (*Reinhardtius hippoglossoides*) (turbot)
J 25(12): 2721 (first record in Bay of Fundy)
CJG 14 : 13, 44 (Nfld. investigations; commercial landings)
15 (36: length distribution, Nfld.; commercial landings, 1952–67)
A 108 (1966 Canadian ICNAF studies: commercial catches; distribution)

Halibut, Pacific (*Hippoglossus stenolepis*)
T 11, 22, 30, 46, 62, 81 (in experimental B.C. trawling)
A 90, 103 (fishery trend along N America Pac. coast)

Halichoerus grypus (*see* Seal, grey)

Halliday, Ralph Gilmore
J 25(2): 421 (*Parasudis truculentus* off N.S.)

Halosaccion ramentaceum (a red seaweed)
S 1239 (sterols)

Halsey, Thomas Gordon
J 25(1): 81 (winter limnology of 3 small eutrophic lakes)

Hammerhead (*Sphyrna* species) (hammerhead shark)
A 108 (1966 Canadian ICNAF studies: catch)

Hammerhead, scalloped (*Sphyrna lewini*) (hammerhead shark)
S 1244 (a corticosteroid 1α-hydroxylase in interrenal tissue)

Hamoir, G.
J 25(12): 2711 (fish creatine kinase in electrophoretic patterns)

Handling (*see also* Apparatus)
J 25(4): 733 (of trap-caught Atl. cod re quality of frozen)
B 166 : 38 (& holding of live American eels)
T 69 (pumps for unloading fish from fishing vessels)

Hansen, Roy Penrose
S 1193 (diastereomers of phytanic & pristanic acids)

Harling, Wayne Robert
T 22 (*G. B. Reed* groundfish cruise No. 67-1)
46 (*G. B. Reed* groundfish cruise No. 67-2)
81 (*G. B. Reed* groundfish cruise No. 68-2)

Harpoon
J 25(1): 177 (adapted for tagging surface-swimming fish)

Hart, John Lawson
A 99 (fisheries production from the NW Atl.)

Hart, John Sanford
J 25(12): 2603 (goldeye respiration)

Hartman, Gordon Fredrick
J 25(1): 33 (S B.C. trout distribution)

Harvey, Harold Henry
J 25(6): 1115 (kokanee & sockeye sounding response)

Hasler, Arthur Davis
J 25(4): 711 (changing seasons on yellow perch schooling)
(11): 2515 (invertebrates calorific values)

Hatchery
J 25(3): 585 (controlled-environment incubator for small marine fish eggs)
(7): 1390 (re rehabilitation of L. Superior lake trout)
(12): 2643 (furunculosis re brook trout stock)
B 162 : 387 (vs. natural propagation of sockeye salmon)

Hayes, Frederick Ronald
A 77 (work of FRB)

Hearing (*see* Sound, reactions to)

Heart (*see also* Blood)
J 25(4): 695 (*Gaffkya homari* infection of lobster)
(6): 1247 (tissues of Pac. salmon re transaminase activity)
(12): 2643 (furunculosis bacteria in brook trout)

Hecate Strait, B.C. (*see* Queen Charlotte Islands region)

Hematin; Hematology; Hemoglobin; Hemolymph (*see* Blood)

Hemichordata
T 60 (in Strait of Georgia benthos biomass)

Hemilepidotus hemilepidotus (*see* Irish lord, red)

Hemilepidotus spinosus (*see* Irish lord, brown)

Heming Lake, Man.
J 25(2): 255 (staining small fish for populations estimation)
(11): 2523 (*Triaenophorus nodulosus* in burbot)

Hemioniscus balani (parasitic isopod)
J 25(6): 1161 (E coast N America distribution)

Hemiselmis virescens (a marine cryptomonad)
S 1198 (N compounds supporting phototrophic growth)

Hemoglobin; Hemolymph (*see* Blood)

Heney Lake, Que.
J 25(9): 1813 (F) (sympatric populations of giant & dwarf smelts)

Hepatopancreas
J 25(11): 2461 (accumulation of natural ^{65}Zn in crustacean)
S 1226 (positional distribution of fatty acids in triglycerides)

Herbicide
CDG 1 (2,4-D ester for eelgrass control on oyster beds)
S 1210 (2,4-D ester for eelgrass control & effect on oysters, etc.)
A 109 (same as CDG 1 above)

Hergenrader, Gary Lee
J 25(4): 711 (changing seasons on yellow perch schooling)

Herlinveaux, Richard Henry
T 70 (oceanographic features of central B.C. coast waters)

Herring, Atlantic (*Clupea harengus* (*harengus*))
J 25(2): 431 (interrenal tissue biosynthesis of sterones)
(4): 639 (catalysis of flesh oxidative rancidity by metal ions)
(5): 906 (as swordfish feed in NW Atl.)
(6): 1169 (tidewater larvae sampling with buoyed & anchored nets)
(11): 2503 (otolith growth abnormality)
CJG 14 : 18 (Nfld. spawnings in recent years)
15 (migrations, distribution, spawning, & landings of Nfld.)
CVG 40 (antioxidants for spontaneous heating control in bulk meal)
T 5 (studies of fatness condition)
49 (age determination from scales & otoliths)
57 (length & age distribution, Bay of Fundy
58 (landings in Nfld. re stock distribution & abundance)
80 (stocks, Gulf of St. Lawrence & N.S. Banks)
S 1192 (oil structure resolution by GLC)
1193 (oil phytanic & pristanic acid diastereomers)
1226 (fatty acids positional distribution in fat triglycerides)
A 92 (abnormal water temperatures effect on fishery)
94 (biology; fishery, 1940–65 landings)
95 (recent investigations in Nfld. waters)
96 (resources research needs)
97 (nutritive value of meal)

Abbreviations: J — Journal; B — Bulletin; AR — Annual Report; R — Review; *Circular series*: CDG — Dartmouth; CHN — Halifax; CJG — St. John's; CNG, CNS — Nanaimo; CSG — St. Andrews; CVG — Vancouver; T — Technical Reports; MSP — Miscellaneous Special Publications; S — Studies; A — Interpretive Articles.

98 (use for fish protein concentrate and low-fat meal)
99 (fishery yields, 1952–64)
108 (1966 Canadian ICNAF studies: commercial catches; spawning; age; tagging; condition)

Herring, lake (*Coregonus artedi(i)*) (*see also* Tullibee)
J 25(4): 667 (re Great Lakes species succession & exploitation)
(8): 1667 (cytotaxonomic relation to other Great Lakes coregonids)
(10): 2111 (scales annulus formation in hybrid with bloater)

Herring, Pacific (*Clupea pallasii*)
J 25(3): 589 (schools behaviour to midwater trawl)
CNG 86 (B.C. 1968 spawn deposition)
CVG 40 (antioxidants for spontaneous heating control in bulk meal)
T 11, 81 (in B.C. experimental groundfish trawling)
S 1221 (meal effects on chicken egg hatchability)
1228 (isoprenoid fatty acids of oil, re feed)
A 85 (nutrient composition of meal as poultry feed)
97, 98 (meals & by-products)
102 (1967 scanty spawning in B.C.)
105 (reasons for decline of B.C. stocks)

Hexagrammos decagrammus (*see* Greenling, kelp)

Hexagrammos stelleri (*see* Greenling, white-spotted)

Hickman, Cleveland Pendleton, Jr.
J 25(8): 1651 (inorganic iodide binding)

Hierarchy (*see* Behaviour)

Hierops thompsoni (a lanternfish)
J 25(3): 457 (in N B.C. midwater trawl catches)
T 11 (in experimental B.C. midwater trawling)

Hines, James Alexander
S 1261 (degradation of adenine nucleotides)

Hingley, Helen Joyce
J 25(2): 267 (filter-feeding organism dimethyl-β-propiothetin retention)
(10): 2083 (cod flesh lipid fatty acids)

Hiodon alosoides (*see* Goldeye)

Hippoglossoides (species)
T 34 (systematics)

Hippoglossoides elassodon (*see* Sole, flathead)

Hippoglossoides platessoides (*see* Plaice, American)

Hippoglossus hippoglossus (*see* Halibut, Atlantic)

Hippoglossus stenolepis (*see* Halibut, Pacific)

Histology (*see also* Cytology)
J 25(2): 373 (bluegill retina)
(3): 541 (*Polinices* podium re expansion)
(4): 695 (lobster heart & gills infected with *Gaffkya homari*)
(5): 863 (cornea ultrastructure in 3 trout species)
(6): 1115 (kokanee pneumatic duct re swim bladder function)
(7): 1339 (scallop muscle ultrastructure)
(7): 1465 (salmon & trout pituitary & interrenal tissue re hormones)
(8): 1739 (spinal ganglia in teleosts)
(9): 2001 (F) (walleye & sauger retina)
(11): 2461 (distribution of natural ^{65}Zn in crustacean tissues)
(11): 2467 (of fungus attack on chinook salmon)
(12): 2691 (^{65}Zn metabolism in freshwater mussel)

History (*see also* Life history)
J 25(4): 667 (Great Lakes species succession & fishery exploitation)
B 162 : 43 (sockeye salmon utilization)
A 93 (of lobster transplants to B.C.)
106 (of transplants of *Oncorhynchus* salmon species to Great Lakes, Hudson & James Bay, & Atl. coast)

Hoar, William Stewart
J 25(6): 1115 (kokanee & sockeye sounding response)

Hodder, Vincent Mackay
A 95 (herring investigations in Nfld. waters)

Hodgins, Harold O.
J 25(3): 473 (salmon blood lactate after exercise)

Hoffman, Ethelwyn Gourley
J 25(3): 439 (laboratory-reared *Paralithodes platypus* larvae)

Hogan, James William
J 25(4): 615 (bluegill & channel catfish brain acetylcholinesterase)
(7): 1517 (fish brain esterases)
(8): 1571 (organophosphate degradation)

Hogman, Walter J.
J 25(10): 2111 (coregonid annulus formation)

Holding of live fish
B 166 : 38 (American eels)
T 78 (octagonal pound)

Hollister, Henry John
T 32 (B.C. coast sea surface temperatures & salinity)
82 (1966 B.C. coast sea surface temperature & salinity)

Holmberg, Deanna Marie
T 7 (B.C. trawl fishery 1966 catch & effort statistics)
12 (1935–65 Pac. cod Canadian & U.S. catch statistics)
19 (1966 B.C. trawl fishery)

Holothurians (*see also* Sea cucumber)
T 25, 35, 59, 60, 73 (in Strait of Georgia benthos biomass)

Homarus americanus (*see* Lobster)

Homing (*see also* Migration)
J 25(5): 867 (re olfaction & vision in homing chinook salmon)

Hooper, Shirley Norma
S 1227 (fin whale lipids — fin whale milk)
1228 (isoprenoid fatty acids re whale oils)
1254 (stereoisomerism in fatty acids)

Horne, David Alexander
S 1251 (silica gel steroid recovery)

Hormones (*see also* Cortisol)
J 25(2): 431 (interrenal tissue biosynthesis of sterones in Atl. herring)
(7): 1465 (metopirone effect on pituitary–interrenal function of sockeye salmon & rainbow trout)
(12): 2549 (1α-hydroxycorticosterone function in skate)
S 1205 (biological activity of 1α-hydroxycorticosterone in skates)
1224 (androstenedione to testosterone conversion by lobster tissues)
1244 (corticosteroid 1α-hydroxylase in elasmobranch interrenals)

Hourston, Alan Stewart
J 25(11): 2503 (herring otolith growth cessation)
T 49 (ageing of herring)
58 (Nfld. herring catches & landings)

Houston, Arthur Hillier
J 25(1): 173 (rainbow trout hematological correlations)

Hoyle, Richard James
J 25(2): 363 (Atl. salmon sperm subzero preservation)
(6): 1295 (frozen salmon sperm fertilization)
S 1226 (fatty acids positional distribution)
1233 (fatty acids incorporation into mammal triglycerides & phospholipids)

Huang, Chau-Ting
J 25(8): 1651 (inorganic iodide binding)

Huang, Pei Chu (*see* Hwang, Pei Chu)

Hudson Bay and James Bay
A 106 (unsuccessful & further possibilities of introducing *Oncorhynchus* into)

Hulburt, Edward M.
J 25(12): 2609 (W Gulf of Maine waters)

Hunn, Joseph Bruce
J 25(1): 25 (rainbow trout M.S. 222 excretion)

Hunter, John Roe
J 25(2): 393 (light on jack mackerel schooling & feeding)

Huron, Lake (*see also* Great Lakes)
A 106 (transplantation of *Oncorhynchus* salmons into)

Hwáng, Pei Chu
J 25(12): 2623 (Atl. cod sperm preservation)
S 1226 (fatty acids positional distribution)
1233 (fatty acids incorporation into mammal triglycerides & phospholipids)

Hyas coarcticus (*see* Crab, toad)

Hybrids; Hybridization (*see also* Splake)
J 25(1): 101 (white × largescale suckers re isolating mechanisms)
(7): 1317 (muscle proteins inheritance in redside shiner × peamouth chub)
(7): 1323 (muscle enzyme difference in brook × brown trout)
(10): 2111 (scales annulus formation in lake herring × bloater)
B 162 : 400 (among 5 Pac. salmon species)

Hydrography (*see also* International Commission for the Northwest Atlantic Fisheries; Limnology; Oceanography; Topography)
J 25(1): 81 (of 3 SW B.C. lakes re trout mortality)
(6): 1181 (L. Michigan)
(11): 2327 (Fe, Mn, & Ti in St. Lawrence R. estuary glacial sediments)
(11): 2427 (dissolved O_2 & salinity re Gulf of Maine recent temperature trends)

T 77 (St. Margaret's Bay, N.S., re primary productivity)
A 108 (1966 Canadian ICNAF studies of Atl.)

Hydrolagus affinis (*see* Chimaera, deepwater)

Hydrolagus colliei (*see* Ratfish)

Hydroxylamine
B 167 : 93 (determination in sea water)

Hypomesus pretiosus (*pretiosus*) (*see* Smelt, surf)

Hypophysectomy (*see* Pituitary)

Hypoxanthine (*see* Purines)

I

Ice; Icing (*see also* Chilling)
J 25(8): 2059 (re protein extractability & free fatty acid in stored cod muscle)
(8): 2071 (re quality of chemically preserved haddock fillets)

Icelinus filamentosus (*see* Sculpin, threadfin)

Icelinus tenuis (*see* Sculpin, spotfin)

Icichthys lockingtoni (*see* Medusafish)

ICNAF (*see* International Commission for the Northwest Atlantic Fisheries)

Ictalurus nebulosus (*see* Bullhead, brown)

Ictalurus punctatus (*see* Catfish, channel)

Idler, David Richard
J 25(2): 299 (refrozen cod storage quality)
(2): 363 (Atl. salmon sperm subzero preservation)
(2): 431 (teleost biosynthesis)
(4): 733 (Nfld. trap-caught cod quality after single & double freezing)
(6): 1295 (frozen salmon sperm fertilization)
(12): 2549 (elasmobranch interrenalectomy & stress)
(12): 2623 (Atl. cod sperm preservation)
S 1205 (1α-hydroxycorticosterone activity)
1224 (conversion of androstenedione to testosterone by lobster tissues)
1239 (red algae sterols)
1244 (steroid 1α-hydroxylation in elasmobranchs)
1251 (silica gel steroid recovery)
A 98 (herring for fish protein concentrate & low fat meal)

Iliamna Lake, Alaska
J 25(3): 485 (spawning sockeye behaviour on island beaches)

Illex illecebrosus (*illecebrosus*) (*see* Squid, short-finned)

Illumination (*see* Light, reactions to)

Imagotaria downsi (*see* Sea lion)

Inconnu (*Stenodus leucichthys*)
J 25(8): 1667 (cytotaxonomic relation to other Great Lakes coregonids)
T 33 (in Great Slave L. fishery)

Incubator (*see* Hatchery)

Index
B 164 (subject–author, for Fisheries Research Board publications and certain relevant publications, 1900–1964)

Ingles, Charles James
S 1245 (protamine biosynthesis)

Inopsetta ischyra (*see* Sole, forkline)

Inosine (*see* Purines)

INPFC (*see* International North Pacific Fisheries Commission)

Insecticides (*see also* Pesticides; Pollution; Toxicants)
J 25(1): 189 (DDT residues & metabolites in Atl. coast fishes)
(8): 1571 (fish liver phosphatase degradation of organophosphate)
(8): 1621 (effect of Sevin on cockle clam survival & growth)
(9): 1787 (DDT effect on brook trout reproduction)
(9): 1797 (dieldrin residues in goldfish after aldrin ingestion)
(11): 2321 (DDT degradation in Atl. salmon)
(11): 2443 (DDT effect on brook trout growth & stress resistance)
(12): 2677 (DDT effect on brook trout lateral line response)
T 6 (evaluating salmon fisheries damage from N.B. forest spraying)
S 1241 (disproval of *Nemoura* stonefly DDT tolerance)

Insects, aquatic (*see also* Insecticides; Mayflies; Midges)
J 25(7): 1423 (N American distribution of *Taeniopteryx* stoneflies)

Instrumentation (*see* Apparatus)

International Commission for the Northwest Atlantic Fisheries (ICNAF)
S 1206 (characteristics of salmon from Labrador Sea & off W Greenland)
1207 (American plaice catches diurnal variation on Grand Bank)

1208 (otolith age validation in Labrador cod)
1209 (offshore fishing effect on inshore Labrador cod fishery)
1211 (changes in halibut fishery in ICNAF subareas, 1954–64)
1212 (age determination of greysole off N.S.)
1213 (length–weight relations for American plaice, witch and yellowtail flounder)
1215 (recent sea temperature variations in ICNAF Subarea 4)
1216 (sea & air temperature anomalies off Cape Spear, Nfld.)
1217 (revised growth rate estimate between Greenland & Miramichi R.)
1218 (salmon tagging in Maritime provinces, 1964–66)
A 99 (fisheries production from ICNAF areas, 1952–64)
108 (research reports for 1966 in Canadian areas)

International North Pacific Fisheries Commission (INPFC)
S 1230 (Canadian Pac. salmon spawning populations)
A 86 (1966 salmon & oceanographic research results)

Interrenal tissue (*see* Adrenal gland)

Intestine
J 25(9): 1797 (dieldrin accumulation in goldfish, after aldrin ingestion)
(11): 2365 (2 new tapeworm species in deepwater chimaera)
(12): 2643 (furunculosis bacteria in brook trout)

Invertebrates (*see* Lists of aquatic invertebrates; *also* classifications and names of species)

Iodine compounds
J 25(8): 1651 (inorganic iodide binding plasma protein)

Iodine value (*see* Acids, fatty)

Irish lord, brown (*Hemilepidotus spinosus*)
J 25(12): 2665 (associations with other fishes off Oregon coast)

Irish lord, red (*Hemilepidotus hemilepidotus*)
T 11 (in experimental B.C. midwater trawling)

Irish moss (*Chondrus crispus*)
T 43 (ecology in Nfld. waters)

Iron compounds
J 25(4): 639 (catalyzing marine flesh oxidative rancidity)
(6): 1229 (re phytoplankton ecology in an Ont. reservoir)
(11): 2327 (in St. Lawrence R. estuary glacial marine sediments)
(12): 2575 (re limnology of arctic fresh waters)
B 167 : 97 determination in sea water)
A 85 (in freshwater fishmeals)

Irradiation (*see also* Isotopes; Radiation)
A 77 (fish & lobster meat preservation by ^{60}Co gamma)
78 (brief summary of preservative effect)

Irwin, Brian
T 77 (St. Margaret's Bay primary production)

Isochrysis galbana (marine planktonic alga)
S 1194 (antibacterial products from extracts)
1197 (aldolase activity)

Isopiestic measurements
S 1234 (of H_2O–NaCl–Na_2SO_4 system re sea water)

Isopoda (*see also* Gribble)
J 25(1): 157 (*Mesidotea entomon* biology, Chignik Lakes, Alaska)
(6): 1161 (*Hemioniscus balani* distribution)
T 25, 35, 59, 60, 73 (in Strait of Georgia benthos biomass)
43 (on Irish moss)

Isopsetta isolepis (*see* Sole, butter)

Isotopes (other than ^{14}C) (*Note*: data on use of ^{14}C not indexed separately because of its frequent use; *see* Biosynthesis, etc.)
J 25(3): 591 (trout growth effect on ^{65}Zn retention)
(8): 1651 (^{125}I re plasma protein-bound inorganic iodide)
(10): 2101 (^{15}N in studies of N utilization in subarctic lake)
(10): 2219 (loss of radioactivity in phytoplankton stored on filters)
(11): 2461 (tissue distribution of natural ^{65}Zn in Crustacea)
(12): 2691 (^{65}Zn metabolism in freshwater mussel)
A 77 (^{60}Co irradiation for flesh pasteurization)

Isurus oxyrinchus (*see* Mako)

J

Jaffray, June I.
J 25(4): 733 (Nfld. trap-caught cod quality after single & double freezing)

Jangaard, Peter Michael
J 25(11): 2419 (harp & hooded seal lipids)
CHN 32 (fish paste products)
33 (handling shrimp)
34 (Maine shrimp industry)
A 89 (handling Atl. coast shrimp)

James Bay (*see* Hudson Bay)

Japan
J 25(4): 625 (marine biosynthesis in Aburatsubo Inlet)
(12): 2527 (re brown trout world distribution)
A 90, 103 (extension of fisheries into NE Pac.)

Jellyfish (*see also* Medusae)
J 25(8): 1561 (*Cyanea capillata* lipids fatty acids composition re turtle feed)
CNG 84 (popular description of some NE Pac. Ocean)
A 108 : 18 (indications of association of *C. capillata* with Atl. cod larvae)

Jenkinson, Donald William
J 25(5): 1067 (ageing salmon by otoliths & scales)
CNS 26 (1957–63 B.C. chum salmon catches)

John, Kenneth Rydal
J 25(2): 373 (bluegill retinomotor rhythms)

Johnson, Clifford Ray
J 25(4): 807 (*Enophrys bison* food)

Johnson Creek, Idaho
J 25(7): 1453 (station permanence studies of juvenile salmon & trout)

Johnston, Charles Edward
J 25(9): 1901 (*Salmo salar* skin & scales)

Jonas, Richard Edmund Ernest
J 25(10): 2157 (muscle dissolution by lysolecithin)

Jones Creek (Upper), Ont.
J 25(6): 1199 (water temperature effects on fish feeding)

Jones, Leslie Thomas
J 25(5): 1071 (*Meganyctiphanes norvegica* off W Greenland)

Jordan, Carlisle Marconi
J 25(12): 2717 (cyprinodontids upper lethal temperatures)

Jordan, Carol
S 1258 (proteinase from a pseudomonad)

Jordan, Fred Paul
T 24 (salmon enumeration & sampling data, Babine R., 1961–66)

Judd, James Mark
J 25(7): 1333 (marking fish with stable strontium)

K

Kabata, Zbigniew
J 25(2): 321 (Chondracanthidae from B.C. fish)
(9): 1923 (*Caligus curtus* Müller, 1785)

Kalff, Jacob
J 25(12): 2575 (arctic fresh waters)

Karluk Lake, Alaska
B 162 : 187, 201 (re sockeye salmon studies)

Katsuwonus pelamis (*see* Skipjack)

Ke, Paul Jean
J 25(5): 1061 (redfish & flatfish oils re fatty acid composition)
(11): 2419 (harp & hooded seal lipids)

Keast, Allen
J 25(2): 285 (black crappie feeding biology)
(6): 1133 (lake fishes feeding & consumption)
(6): 1199 (feeding Great Lakes fishes at low temperatures)

Keleher, James John
T 33 (fishermen & Great Slave L. winter fishery 1957–63)
39 (computer tape system for processing fisheries data)
A 100 (keystone freshwater fishes)

Kennedy, Owen David
T 37 (zooplankton net for coastal observations)

Kennedy, V. S.
S 1212 (greysole age determination by otoliths)

Kennedy, William Alexander
J 25(10): 2247 (FP-66 tag on sablefish growth)
T 74 (1964–65 sablefish study)
78 (octagonal pound for live fish)

Kerns, Orra Edwin, Jr.
J 25(3): 485 (sockeye spawning)

Kerswill, Charles James
A 83 (criteria for pesticide residues)

Ketchen, Keith Stuart
T 12 (1935–65 Pac. cod Canadian & U.S. catch statistics)
23 (Pac. cod length composition 1951–66)

A 90 (Pac. coast marine fisheries trends)
103 (Pac. coast marine fisheries trends)

Keys
J 25(5): 954 (N American Atl. & arctic coast *Anonyx* amphipods)
(7): 1423 (E N American *Taeniopteryx* stoneflies)
(9): 1892 (otariid subfamilies)
CNG 84 (NE Pac. marine zooplankton major groups)
T 55 (51: adult B.C. marine Copeopda; 109: pelagic amphipods)

Kidney (*see also* Adrenal tissue)
J 25(6): 1247 (tissues of Pac. salmon re transaminases activity; & kidney-diseased sockeye)
(9): 1797 (dieldrin accumulation in goldfish, after aldrin ingestion)
(12): 2643 (furunculosis bacteria in brook trout)

Killifish, banded (*Fundulus diaphanus*)
J 25(6): 1133 (diel feeding habits)
(6): 1199 (low temperature effects on feeding in 3 Ont. localities)
(12): 2717 (upper lethal temperatures at various salinities after isosmotic acclimation)

Kinase (*see* Enzymes)

King, Frederick Jessop
J 25(11): 2453 (dimethyl sulfide & clam odor)

King, George Robert
J 25(7): 1377 (Apostle Is. lake trout rehabilitation)

Kiyi (*Leucichthys kiyi*)
J 25 (4): 667 (re Great Lakes species succession & exploitation)
(8): 1667 (cytotaxonomic relation to other Great Lakes coregonids)
(10): 2111 (scales annulus formation in artificially reared)

Knight, William
J 25(6): 1303 (polemic on mathematical treatment of asymptotic growth)

Knowles, Charles Otis
J 25(4): 615 (bluegill & channel catfish brain acetylcholinesterase)
(7): 1517 (fish brain esterases)
(8): 1571 (organophosphate degradation)

Kogia simus (*see* Whale, pigmy sperm)

Kohler, Allan Carl
J 25(3): 555 (Gulf of St. Lawrence cod)
T 80 (N.S. Banks & Gulf of St. Lawrence fish stocks)
S 1211 (ICNAF Subareas 3 & 4 halibut fishery)

Kokanee (*Oncorhynchus nerka kennerlyi*) (landlocked sockeye salmon)
J 25(2): 409 (distribution & nomenclature of N American)
(2): 415 (variation in gillraker number, N American)
(4): 690 (introduction into L. Michigan & Georgian Bay)
(6): 1115 (sounding response)
B 162 : 236 (as food competitor of young sockeye salmon)
A 106 (history of transplantations to 4 of the Great Lakes)

Kouchibouguac Bay, N.B.
J 25(12): 2683 (artificial reefs for lobsters)

Krebs cycle
S 1222 (molar responses for methyl esters of metabolic acids)

Krishnan Kutty, M.
J 25(6): 1291 (age of exploitation)

Kuhlia scandricensis (*see* Aholehole, Hawaiian)

Kutty, Methil Narayan
J 25(8): 1689 (goldfish & trout respiratory quotients)

L

Laastuen, Lester Emil
J 25(3): 611 (juvenile salmonid skin pallor by guanidine compounds)

Laboratories, Fisheries Research Board of Canada
R 1965–1966: 13–110 (review of programs; lists of scientific staffs)
MSP 10 : 17 (list, with addresses)

Labrador; Waters off Labrador (*see also* International Commission for the Northwest Atlantic Fisheries; Newfoundland)
J 25(12): 2749 (possible effect of harbour seal bounty re Atl. cod codworm infestation)
B 166 : 45 (eel fishery)
S 1206 (characteristics of salmon)
1208 (otolith age validation of cod)
1209 (offshore fishing effect on inshore cod fishery)

Lactic acid; Lactate
J 25(1): 15 (lactic acidosis of channel catfish blood in anoxia)

(3): 473 (blood lactate re exercised salmon mortality)
(4): 738 (of trap-caught Nfld. cod before & after freezing)
(5): 837 (of exercised Atl. cod blood & muscle after exercise)
(7): 1323 (dehydrogenase in 3 trout species)

Lagenorhynchus obliquidens (*see* Dolphin, Pacific striped)

Lagopus mutus (*see* Ptarmigan, rock)

Laishley, Edwards James
J 25(2): 299 (refrozen cod storage quality)

Lakelse Lake, B.C. (*see also* Salmon)
B 162 : 181, 155, 246 (re B.C. sockeye salmon studies)
T 10 (age, size, & sex composition of sockeye salmon 1965 & 1966 spawning run)

Lakes (*see also* Great Lakes; Limnology; Waters, natural; *also* names of individual lakes)
J 25(8): 1741 (plankton sampling device for frozen)
(9): 1911 (mathematical description of average vertical temperature distribution)

Lamna nasus (*see* Porbeagle)

Lampanyctus leucopsarus (*see* Lanternfish, smallfin)

Lampanyctus nannochir (a lanternfish)
J 25(3): 457 (in N B.C. midwater trawl catches)
T 11 (as above)

Lampanyctus regalis (*see* Lanternfish, pinpoint)

Lampanyctus ritteri (a lanternfish)
J 25(3): 457 (in N B.C. midwater trawl catches)
T 11 (as above)

Lampetra fluviatilis
T 48 (parasites)

Lampetra japonica (*see* Lamprey, arctic)

Lampetra lamottei (*see* Lamprey, American brook)

Lampetra mariae
T 48 (parasites)

Lampetra planeri (*see* Lamprey, western brook)

Lamprey, American brook (*Lampetra lamottei*)
T 48 (parasites)

Lamprey, arctic (*Lampetra japonica*)
T 48 (parasites)

Lamprey, brook (*Lampetra lamottei*) (*Entosphenus lamottei*)
J 25(7): 1521 (infection by *Aeromonas* in Great Lakes)

Lamprey, Pacific (*Lampetra tridentata*) (*Entosphenus tridentata*)
T 11 (in B.C. experimental midwater trawling)

Lamprey, sea (*Petromyzon marinus*)
J 25(4): 667 (re Great Lakes species succession & exploitation)
(7): 1368 (effect on walleye in Nipigon Bay, Ont.)
(7): 1521 (infection by *Aeromonas* in Great Lakes)
T 48 (parasites)

Lamprey, western brook (*Lampetra planeri*)
T 48 (parasites)

Lance, sand (*see* Sand lance)

Land, Jacob van der
J 25(11): 2365 (2 new species of *Gyrocotyle*)

Landings (*see* Catches)

Lane, John Perry
J 25(2): 299 (refrozen cod storage quality)

Lanternfish, blue (*Tarletonbeania crenularis*)
J 25(3): 457 (in N B.C. midwater trawl catches)
(4): 825; (5): 1086 (as feed in NE Pac. Ocean)
T 11 (in experimental B.C. midwater trawling)

Lanternfish, pinpoint (*Lampanyctus regalis*)
J 25(3): 457 (in N B.C. midwater trawl catches)
T 11 (as above)

Lanternfish, smallfin (*Lampanyctus leucopsarus*)
J 25(3): 457 (in N B.C. midwater trawl catches)
(5): 1086 (as feed in NE Pac. Ocean)
(8): 1739 (spinal ganglia position re taxonomy)
T 11 (in experimental B.C. midwater trawling)

Lanternfish, theta (*Diaphus theta*)
J 25(3): 457 (in N B.C. midwater trawl catches)
T 11 (in experimental B.C. midwater trawling)

Lanternfishes (general, or species uncertain)
J 25(3): 457 (in N B.C. coast midwater trawl catches)

(5): 907 (as swordfish feed in NW Atl.)
(12): 2561 (as cetacean feed)
T 11 (in experimental midwater trawling, Queen Charlotte Is. region)
22, 46, 81 (in experimental B.C. groundfish trawling)

Lantz, Andrew William
A 85 (freshwater fishmeals nutrient composition)

Larkin, Peter Anthony
J 25(12): 2589 (Fraser R. white sturgeon)

La Ronge, Lac, Sask.
J 25(10): 2091 (lake whitefish growth & reproduction)

Larus (*see* Gulls)

Larvae (*see also* name of adult organism)
T 81 : 5 (identification of 12 *Sebastodes* species)

Lau, Yan Chee
S 1248 (algal phospholipase C, properties)

Launce, sand (*see* Sand lance)

Lauzier, Louis Marcel
S 1215 (ICNAF Subarea 4 temperature variations)
A 82(F) (marine climate)
92 (abnormal water temperatures affect herring fisheries)

Lawler, George Herbert
J 25(2): 255 (Heming L., Man., fish stain marking)
(11): 2523 (*Triaenophorus nodulosus* in burbot)

Lawrence, Donald John
J 25(5): 1079 (inertial oscillations at 42°N)

Lebbeus (hippolytid shrimps)
J 25(2): 347 (Queen Elizabeth Is., Canadian arctic)
S 1260 (adaptation re other shrimps in NW Atl.)

LeBrasseur, Robin John
CNG 84 (zooplankton of NE Pac. Ocean)
T 37 (zooplankton net for coastal observations)

Lecithin and derivatives
J 25(10): 2157 (fish muscle homogenates dissolution by lysolecithin)

Legault, Roméo O.
J 25(9): 1813 (F) (smelt spawning)

Length (*see also* Growth; Size; Weight)
J 25(4): 657 (vs. age & weight of Ungava round whitefish)
(4): 667 (distribution of L. Michigan bloaters)
(7): 1377 (distribution changes in L. Superior lake trout)
(7): 1511 (Sask. R. delta lake sturgeon)
(11): 2403 (re morphology of coho salmon parr–smolt transformation)
(12): 2651 (Atl. salmon hemoglobin multiplicity increase with)
(12): 2743 (estimating mean weight from length statistics)
CJG 15 (distribution, Nfld. Greenland halibut)
T 23 (composition of B.C. trawled Pac. cod)
57 (& age distribution, Bay of Fundy herring)
62 (frequency of Pac. cod)
74 (fork vs. dressed, of sablefish)
S 1206 (of salmon from Labrador Sea & off W Greenland)
1213 (re weight of American plaice, witch & yellowtail flounders)

Lepeophtheirus (*see* Salmon-lice)

Lepidopsetta (species)
T 34 (systematics)

Lepidopsetta bilineata (*see* Sole, rock)

Lepomis gibbosus (*see* Pumpkinseed)

Lepomis macrochirus (*see* Bluegill)

Leptocottus armatus (*see* Sculpin, Pacific staghorn)

Lestidium ringens (*see* Barracudina, slender)

Leucichthys (*see* following species; *also Coregonus* species)

Leucichthys alpenae (*see* Cisco, longjaw)

Leucichthys hoyi (*see* Bloater)

Leucichthys johannae (*see* Cisco, deepwater)

Leucichthys kiyi (*see* Kiyi)

Leucichthys nigripinnis (*see* Cisco, blackfin)

Leucichthys reighardi (*see* Cisco, shortnose)

Leucichthys zenithicus (*see* Cisco, shortjaw)

Leuciscus cephalus (*see* Chub)

Leuroglossus stilbius (*see* Smoothtongue, California)

Levin, Catherine B.
J 25(5): 1091 (permanent dry-mounted teleost chromosomes)

Levings, Colin David
J 25(8): 1743 (fertilized eggs of butter sole)
T 36 (rock sole growth rates in NE Pac.)
62 (*G. B. Reed* groundfish cruise to Hecate Strait)

Li, Ming Fang
S 1214 (hemagglutinins from oyster hemolymph)
1258 (proteinase from a pseudomonad)

Lice (*see* Salmon-lice)

Life history (*see also* names of organisms)
B 162 (sockeye salmon)
165 (carp)
166 (American eel)
T 31 (Atl. mackerel)
S 1201 (gray seal off E Canada)
1255 (NW Atl. capelin)

Light, reactions to (*see also* Diel habits)
J 25(2): 373 (bluegill retinomotor rhythms)
(2): 393 (re jack mackerel feeding)
(4): 711 (re yellow perch schooling behaviour)
(6): 1285 (re brown trout activity)
(9): 1901 (re guanine & hypoxanthine formation in Atl. salmon)
(10): 2111 (effect on coregonid scale annulus formation)
(10): 2143 (re orientation of American eels toward spawning area)
S 1207 (diurnal variation in American plaice catches)

Lighthouse oceanographic stations, B.C. coast
T 32, 82 (surface temperatures & salinities, 1965, 1966)

Limacina (*see* Pteropoda)

Limanda aspera (*see* Sole, yellowfin)

Limanda ferruginea (*see* Flounder, yellowtail)

Limnology (*see also* Benthos)
J 25(1): 33 (pH & dissolved solids of SW B.C. streams)
(1): 81 (of 3 SW B.C. lakes re trout mortality)
(6): 1181 (re benthic environment of upper Great Lakes)
(6): 1229 (re phytoplankton ecology of L. Belwood, Ont.)
(9): 1911 (mathematical treatment for average vertical temperature distribution)
(12): 2575 (physical & chemical of some Alaska and N.W.T. lakes & rivers)
B 162 : 177 (of sockeye salmon lakes)

Limnoria lignorum (*see* Gribble)

Lindsey, Casimir Charles
J 25(9): 1987 (large fish muscle temperatures)

Lindsey, James Keith
T 29 (Maritime area Atl. salmon catches, 1949–65)
87 (nonlinear response surfaces)

Lingcod (*Ophiodon elongatus*)
J 25(8): 1539 (postmortem muscle glycogen & starch degradation)
(8): 1651 (plasma protein-bound inorganic iodide)
(12): 2665 (associations with other fishes off Oregon coast)
T 7, 11, 19, 22, 30, 46, 56, 62, 81, 89 (in B.C. experimental or commercial trawling)
A 91 (1956 & 1966 B.C. landings for mink feed)

Lilly, George Richard
T 43 (Irish moss ecology in Nfld. waters)

Liparis fucensis (*see* Snailfish, slipskin)
T 11 (in B.C. experimental midwater trawling)

Lipase (*see* Enzymes; Lipids)

Lipids (*see also* Acids, fatty; Phospholipids; Rancidity; Triglycerides)
J 25(8): 1555 (possible mechanism of reserve utilization in fish)
(8): 1561 (fatty acids composition of jellyfish & turtle)
(8): 1603 (of marine phytoplankters re taxonomy, etc.)
(10): 2083 (fatty acids distribution in cod flesh)
(11): 2403 (changes in total, during coho salmon development)
(11): 2419 (fatty acids composition of seal milk)
B 167 : 227 (determination of particulate, in sea water)
CVG 40 (action of various antioxidants on herring meal)
S 1227 (fatty acids composition of fin whale milk)
1233 (marine fatty acids incorporation into mink & rat)
1236 (biosynthesis from added substrates by Atl. salmon sperm)
1250 (pancreatic lipase substrate specificity)
A 80 (re fish products nutrition value)

Lippa, Erich Johannes Richard
T 13 (B.C. trawlers & trawl gear)

Lissodelphis borealis (*see* Dolphin, northern right whale)

Lists of aquatic flora (not indexed individually) (*see also* Algae; Seaweeds)
T 3 (Oozy Creek, P.E.I.)
76 (tidal Ostrea L., N.S.)

List of aquatic invertebrates (not indexed individually) (*see also* Checklists; Feed; Production, primary)
T 3 (Oozy Creek, P.E.I.)
25, 35, 59, 60, 73 (quantitative benthic investigations, Strait of Georgia)
43 (found on Irish moss)
76 (tidal Ostrea L., N.S.)
S 1219 (Polychaeta (Errantia) recorded from B.C. since 1923)
1243 (Polychaeta (Sedentaria) recorded from B.C. since 1923)

Lists of fishes (not indexed individually) (*see also* Checklists; Feed)
J 25(7): 1405 (recurrent group analysis of Guinea demersal fish assemblages)
(12): 2561 (identified by otoliths in cetacean stomachs as feed of latter)

Lists of publications (*see* Bibliographies; Publications and reports)

Litchfield, Carter
S 1226 (fatty acids positional distribution)

Little Codroy River, Nfld.
J 25(10): 2165 (Atl. salmon smolt survival & adult utilization)
T 38 (estuarine net counting fence for trapping Atl. salmon)
84 (numbers of salmon & brook trout captured & marked at above fence)
S 1257 (as T 38 above)

Littorina littorea (*see* Periwinkle, common)

Liu, Dickson Lee-Shen
J 25(5): 853 (marine borer caecum glucose metabolism)

Liver; Liver oils
J 25(3): 597 (*Ichthyophonus* fungus infection of yellowtail flounder liver)
(5): 1061 (fatty acid composition of redfish & Atl. "flounder oil")
(8): 1571 (phosphatase degradation of organophosphate insecticides)
(9): 1797 (dieldrin accumulation in goldfish, after aldrin ingestion)
(10): 2083 (fatty acids distribution in Atl. cod lipids of)
(12): 2643 (furunculosis bacteria in brook trout)
S 1193 (pristanic & phytanic fatty acids of herring oil)
1203 (positional distribution of monoenoic fatty acids in triglycerides)
1226 (positional distribution of fatty acids in triglycerides of aquatic animals)
1228 (isoprenic fatty acids of Atl. cod oil, re feed)
1233 (marine fatty acids incorporation into mink & rat)

Lizardfishes (*Synodus* species)
CHN 32 (used in Japanese fish paste)

Lobster (*Homarus americanus*)
J 25(2): 427 (larvae distribution off Pictou, N.S.)
(3): 607 (*Gaffkya homari* effect on hemolymph)
(4): 639 (catalysis of flesh oxidative rancidity by metal ions)
(4): 695 (defense mechanisms interaction with *G. homari*; bactericidal activity of hemolymph serum)
(8): 1729 (O_2 consumption at low temperature)
(9): 1763 (adverse conditions affecting moulting)
(10): 2251 (delay of larvae moult)
(12): 2683 (artificial reef for, in Kouchibouguac Bay, N.B.)
(12): 2723 (in deep water off St. John's, Nfld.)
(12): 2725 (overwintering in burrows, Bideford River, P.E.I.)
CJG 14: 35 (holding & farming in Nfld.)
15: 27 (prefer rocky bottom in Nfld.)
T 44 (progress report on transplant to B.C.)
S 1203 (positional distribution of monoenoic fatty acids in hepatopancreas triglycerides)
1224 (tissues converting androstenedione to testosterone)
1226 (fatty acids positional distribution in hepatopancreas triglycerides)
1261 (muscle adenine nucleotides postmortem degradation)
A 76 (recent biological research in Canada)
93 (large-scale breeding attempt on B.C. coast)

Lochsa River, Idaho
J 25(7): 1453 (station permanence studies of juvenile salmon & trout)

Locomotion
J 25(3): 541 (process in *Polinices* by podium)

Loftus, Kenneth Howard
A 106 (Pac. salmon move east)

Loligo opalescens (*see* Squid)

Longhurst, Alan Reece
J 25(7): 1405 (recurrent species groups in Gulf of Guinea)

Loosejaw, Pacific (*Aristostomias scintillans*)
T 11 (in B.C. experimental midwater trawling)

Lopholithodes mandtii (*see* Crab, box)

Lord, Esther Irene
A 110 (walrus tusk)

Loring, Douglas Howard
J 25(11): 2327 (St. Lawrence R. estuary minerals)

Lota lota (*see* Burbot)

Lowes, Roberta Helen
J 25(11): 2477 (protein electrophoresis re rockfish systematics)

Lumbricinae (*see* Earthworms)

Lumpsucker, smooth (*Aptocyclus ventricosus*)
T 46 (in B.C. experimental groundfish trawling)

Lutjanus analis (*see* Snapper, mutton)

Lycodes diapterus (*see* Eelpout, black)

Lycodopsis pacifica (*see* Eelpout, blackbelly)

Lyopsetta exilis (*see* Sole, slender)

M

MacCallum, Wallace Allison
J 25(2): 299 (refrozen cod storage quality)
(4): 733 (Nfld. trap-caught cod quality after single & double freezing)

M[a]cCrimmon, Hugh Ross
J 25(12): 2527 (world distribution of brown trout)
B 165 (carp in Canada)

MacDonald, J. R.
T 6 (N.B. forest spraying damage to salmon fisheries)

Macdonaldia challengeri (a tapirfish)
J 25(1): 181 (2 new NE Pac. Ocean specimens)

Macek, Kenneth Joseph
J 25(9): 1787 (DDT on brook trout reproduction)
(11): 2443 (trout growth & stress resistance re DDT)

Mackay, Isobel
J 25(4): 657 (Ungava round whitefish age & growth)

MacKay, K. T.
T 31 (mackerel ecological study)

MacKelvie, Robin Maxwell
J 25(2): 423 (brook trout nocardiae infection)

Mackerel, Atka (*Pleurogrammus azonus*) (*P. monopterygius*)
CHN 32 (used in Japanese fish paste)

Mackerel, Atlantic (*Scomber scombrus*)
J 25(1): 189 (DDT residues & metabolites in)
(2): 239 (nucleotide degradation re quality of chilled mackerel muscle)
(5): 907 (as swordfish feed in NW Atl.)
T 31 (ecological study)
80 (stocks, Gulf of St. Lawrence & N.S. Banks)
S 1203 (positional distribution of monoenoic fatty acids in triglycerides)
1226 (fatty acids positional distribution in fat triglycerides)
1228 (isoprenoid fatty acids of oil)
1233 (fatty acids incorporation, through feed, into rat tissues)
A 108 (1966 Canadian ICNAF studies: commercial catches; growth; spawning; tagging)

Mackereljack (*Trachurus symmetricus*)
J 25(2): 393 (light effects on schooling & feeding)
(4): 825 (feeding behaviour in NE Pac.)
A 90, 103 (fishery trend along N America Pac. coast)

Mackerel, Pacific (*Scomber japonicus*)
A 90, 103 (fishery trend along N America Pac. coast)

Mackerel, Sierra (*Scomberomorus sierra*)
J 25(9): 1987 (red & white muscle temperature of recently caught)

MacLean, Iain
S 1254 (stereoisomerism in fatty acids)

Macropinna microstoma (*see* Barreleye)

Magnesium compounds
A 85 (in freshwater fish meals)
108 : 17 ($MgSO_4$ activity coefficient of ions)

Magnin, Étienne
J 25(9): 1831 (F) (*Esox masquinongy*)

Maillard browning (*see* Browning of flesh)

Maine
CHN 34 (1968 shrimp industry)

Maine, Gulf of
J 25(8): 1749 (cause of red water occurrence)
(11): 2427 (recent trends in subsurface temperatures)
(12): 2609 (summer stratification & mixing in western)

Makaira mitsukurii (*see* Marlin, striped)

Mako (*Isurus oxyrinchus*) (mako shark)
S 1244 (a corticosteroid 1α-hydroxylase in interrenal tissue)
A 108 (1966 Canadian ICNAF studies: catch)

Makow, David Mark
J 25(3): 605 (tissue ultrasound backscatter)

Malacocottus kincaidi (*see* Sculpin, blackfin)

Malacology (*see also* Shell; *also* names of classifications and species)
T 2 (distributional checklist & bibliography of B.C. marine Mollusca)

Malic acid; Malates
J 25(8): 1581 (2 forms of malic enzyme in fish muscle sarcoplasm)

Mallotus villosus (*see* Capelin)

Mammals (aquatic) (*see* Porpoise; Sea lion; Seal; Walrus; Whale)

Mammals (land) (*see also* Mink; Rat)
S 1200 (significance of teeth annuli for age determination)

Management
B 162 : 49, 87, 131, 387 (sockeye salmon conservation)
165 : 65 (Canadian fishery regulations for carp)
S 1235 (mathematics of effect of size limits changes on catches)

Manefish (*Caristius macropus*)
T 11 (in experimental B.C. midwater trawling)

Manganese compounds
J 25(4): 639 (re marine flesh oxidative rancidity)
(11): 2327 (in St. Lawrence R. estuary glacial marine sediments)
B 167 : 109 (determination in sea water)
A 85 (in freshwater fishmeals)

Manitoba (*see also* Heming Lake; *also* names of localities and other bodies of water)
A 100 (re distribution & ecology of freshwater fishes & number of species)

Manitou, Lake, Ont.
J 25(11): 2257 (marked vs. tagged lake trout survival)

Mansfield, Arthur Walter
S 1202 (grey seal in E Canadian waters)

Manzer, James Ivan
J 25(5): 1085 (NE Pac. salmon & trout food)

March, Beryl Elizabeth
S 1221 (fish meal supplementation of chicken breeder rations on hatchability)
A 85 (freshwater fishmeals nutrient composition)

Marcotte, Alexandre
A 82 (F) (marine climate)

Margate (*Haemulon album*)
J 25(7): 1441 (attraction with pulsed low-frequency sound)

Margolis, Leo
J 25(9): 1923 (*Caligus curtus* parasitic copepod)

Maria (*see* Burbot)

Markert, John Richard
J 25(11): 2403 (Pac. salmon metamorphosis)

Marketing fishery products
B 165 : 55 (Canadian carp)

Marking (*see also* Migration; Tagging)
J 25(2): 255 (small fish with stain for populations estimation)
(4): 757 (pink salmon for estimation of marine mortality)
(7): 1333 (goldfish by feeding strontium-rich diet)
(7): 1377 (lake trout, L. Superior)
(10): 2165 (re Atl. salmon smolts survival & adults utilization)
(10): 2233 (fluorescent pigment tattooing of fingerling salmonids)
(11): 2257 (survival of marked vs. tagged lake trout)
(11): 2519 (fish by high-frequency electric sparks)
B 162: 19 (young sockeye salmon)
T 84 (Atl. salmon & brown trout, Little Codroy R., Nfld.)
A 107 (of 9 species in N Atl., 1966–67)

Marlin, striped (*Makaira mitsukurii*)
J 25(9): 1987 (red & white muscle temperature of recently caught)

Marquette Lake, B.C.
J 25(1): 81 (limnology re trout mortality)

Marshall, Thomas Lawrence
J 25(12): 2527 (world distribution of brown trout)

Martin, William Robert
A 96 (herring resources research needs)

Maskinonge (*Esox masquinongy*)
J 25(6): 1145 (angler harvest re mortality in 2 Ont. lakes)
(9): 1831 (F) (age & growth in 4 Que. lakes)

Masu (salmon) (*Oncorhynchus masou*)
A 106 (suitability for possible transplantation into the Great Lakes)

Mathematical treatment (*see also* Computer programming)
J 25(3): 591 (growth effect on retention time radionuclide metabolites)
(4): 717 (ration–growth relations for European plaice)
(4): 757 (marine mortality schedules of pink salmon)
(6): 1097 (Bay of Fundy natural tidal oscillations)
(6): 1219 (ocean mortality of Bristol Bay sockeye salmon)
(6): 1291 (age estimation of exploitation at given fishing mortality)
(6): 1303 (polemic on mathematics of asymptotic growth)
(8): 1737 (computer programs for benthic data)
(9): 1911 (for describing average vertical temperature distribution in lakes)
(11): 2349 (direct estimation of fish populations by echo sounding)
(12): 2701 (simplified computation of recruitment rates)
(12): 2743 (estimating mean weights from length statistics)
B 167: 5 (statistical limits re seawater analysis)
T 45 (tables for $\varphi + 2 \arcsin \sqrt{\bar{x}}$)
84 (fluid drag, wire & wind effects on free-floating current followers)
S 1235 (quick methods of estimating size limit changes effect on catches)

Mathews, Stephen Barstow
J 25(6): 1219 (sockeye salmon ocean mortality)

Mating (*see also* Reproduction)
J 25(1): 101 (of white + largescale suckers re hybridization)

Matter, particulate, in natural waters (*see also* Productivity, primary)
J 25(4): 625 (re production & mineralization in a Japan inlet)
(8): 1591 (re rheotaxis of American eel to different stream waters)
B 167: 175, 251 (determination in sea water)
S 1223 (re seasonal variations in benthos feed availability)

Maturation; Maturity
J 25(1): 157 (*Mesidotea entomon* in Chignik Lakes, Alaska)
(7): 1465 (re hormones of sockeye salmon & rainbow trout)
(8): 1775 (N.S. offshore sand launce)
(9): 1813 (F) (index of "giant" smelts, Heney L., Que.)
(10): 2091 (lake whitefish)
B 162 : 353 (sockeye salmon)
165 : 12 (carp)
T 31 (Atl. mackerel)
S 1206 (of salmon from Labrador Sea & off W Greenland)
1259 (of sockeye salmon re clearing of injected radioactive cortisol)

May, Arthur William
T 27 (cod biological data, Strait of Belle Isle)
S 1201 (ptarmigan off Labrador)
1208 (Labrador cod otolith age validation)
1209 (offshore fishing re inshore Labrador cod fishery)

Mayflies
J 25(11): 2515 (caloric content of *Caenis* nymphs)

McAlice, Bernard John
J 25(8): 1749 (red water in Gulf of Maine)

McAllister, Carey Douglas
T 37 (zooplankton net for coastal observations)

McBride, John Raymond
J 25(7): 1465 (metopirone in salmonids)

McCauley, Robert William
J 25(9): 1983 (thermal stress on rainbow trout)

McCrimmon, Hugh Ross (*see* M[a]cCrimmon)

McDermott, Lawrence Alfred
J 25(7): 1521 (*Aeromonas* species infection in Great Lakes lampreys)
(12): 2643 (furunculosis-infected brook trout)

McLachlan, Jack
J 25(8): 1603 (phytoplankter fatty acids)

McLeese, Donald Wilson
J 25(8): 1729 (oxygen consumption of spider crab & American lobster)
(8): 1733 (spider crab temperature resistance)

McLeod, L. E.
T 81 (*G. B. Reed* groundfish cruise No. 68-2)

Meal, fish (*see* Fishmeal)

Medcof, John Carl
J 25(11): 2439 (Atl. salmon scales re spawning)

B 131 (F) (oyster farming in the Maritimes)
S 1199 (ancient oyster & bay scallop shells from Sable Is.)
A 110 (walrus tusk)

Medusae (*see also* Jellyfish)
T 55 : 11 (identification of B.C. marine)

Medusafish (*Icichthys lockingtoni*)
T 11 (in B.C. experimental midwater trawling)

Meekin, Thomas Kirkeeng
J 25(11): 2467 (chinook mortality re *Dermocystidium*)

Megalops cyprinoides (a tropical tarpon)
J 25(1): 197 (microorganisms isolated from diseased)

Meganyctiphanes norvegica (a euphausid)
J 25(5): 1071 (larvae occurrence off Greenland)

Megaptera novaeangliae (*see* Whale, humpback)

Melamphaes lugubris (*see* Melamphid, highsnout)

Melamphid, crested (*Poromitra rugosus*)
T 11 (in experimental B.C. midwater trawling)

Melamphid, highsnout (*Melamphaes lugubris*)
T 11 (in experimental B.C. midwater trawling)

Melanogrammus aeglefinus (*see* Haddock)

Melville, Joanne Megan
J 25(3): 547 (*Clostridium botulinum* growth)

Mendelsohn, Joseph Meyer
J 25(11): 2453 (dimethyl sulfide & clam odor)

Mendota, Lake, Wisconsin
J 25(11): 2515 (caloric values of some invertebrates)

Meristic characteristics (*see also* Morphology; Species, new; *also* Length; Size; Weight; *also* names of organisms)
J 25(5): 877 (*Halargyreus johnsonii*)
(9): 1775 (offshore N.S. northern sand lance)
(11): 2509 (3 rockfishes new to B.C.)
T 31 (Atl. mackerel)
34 (arrowtooth & spinycheek flounder; rock & flathead sole; Pac. cod)
S 1206 (salmon from Labrador Sea & off W Greenland)
A 108 : 20 (yellowtail flounder stocks)

Merluccius bilinearis (*see* Hake, silver)

Merluccius productus (*see* Hake, Pacific)

Mesidotea entomon (*see* Isopoda)

Messieh, Shoukry Naseef
T 57 (Bay of Fundy herring length & age distribution)

Metabolism (*see also* names of metabolic functions)
J 25(3): 591 (mathematics of growth effect on metabolite retention)
(5): 853 (of glucose in *Bankia setacea* caecum)
(12): 2691 (of ^{65}Zn in freshwater mussel)
MSP 10 (fish respirometer)
A 116 (fish respirometer)

Metal ions (*see also* Mineral composition; *also* names of elements)
J25 (4): 639 (re rancidity development in marine muscle)

Michigan, Lake (*see also* Great Lakes)
J 25(4): 672 (species changes in fishery)
(6): 1181 (benthic environment subdivisions)
A 106 (transplantation of *Oncorhynchus* salmons into)

Microcystis aeruginosa (*see also* Phytoplankton)
J 25(6): 1229 (in phytoplankton ecology of an Ont. reservoir)

Microgadus proximus (*see* Tomcod, Pacific)

Micropterus dolomieui (*see* Bass, smallmouth)

Micropterus salmoides (*see* Bass, largemouth)

Microstomus pacificus (*see* Sole, Dover)

Midges
J 25(11): 2515 (caloric content of *Glyptotendipes* larvae & pupae)

Midshipman, northern (*Porichthys notatus*)
J 25(8): 1651 (plasma protein-bound inorganic iodide)
T 7, 22, 56, 62 (in B.C. experimental & commercial trawling)
A 91 (observed in B.C. landings of fish for mink feed)

Migration (*see also* Behaviour; Distribution; Marking; Spawning; Tagging)
J 25(7): 1311 (vertical, of crustaceans: pressure effect on respiration)
(7): 1350 (of walleye in Nipigon Bay region, Ont.)
(12): 2723 (lobsters into deep water)

B 162: 13, 18, 71, 287, 328 (sockeye salmon)
CJG 15 (Nfld. herring)
T 4 (analysis of 1965 Atl. salmon smolt run, Miramichi R., N.B.)
31 (Atl. mackerel)

Mink (in general)
T 7, 19, 56, 89 (utilization of B.C. fishes for feed)
A 91 (as above)

Mink, black (*Mustela vison*)
S 1203 (positional distribution of monoenoic fatty acids in triglycerides)
1233 (marine fatty acids incorporation into tissues)

Minnow, fathead (*Pimephales promelas*)
J 25(6): 1199 (low temperature effects on feeding in 3 Ont. localities)

Miles, Stuart Gordon
J 25(8): 1591 (rheotaxis of elvers)
(10): 2143 (American eel orientation)

Milk
J 25(11): 2419 (lipids fatty acid composition of seals)
S 1203 (positional distribution of monoenoic fatty acids in triglycerides of fin whale)
1227, 1228 (lipids fatty acid composition of fin whale)

Millemann, Raymond Eagan
J 25(8): 1621 (Sevin effects on clams)

Milt (*see* Sperm; Testes)

Mineral composition
A 85 (of freshwater & B.C. herring fishmeals)

Mineralization
J 25(4): 625 (re marine bacteria activity)

Miramichi River, N.B.
T 4 (analysis of 1965 Atl. salmon smolt run)
S 1196 (Cu & Zn mining pollution effects on spawning salmon)
1217 (revised growth rate estimates for salmon returning from Greenland)
1218 (salmon tagging results)

Mitchell, Edward Dick, Jr.
J 25(9): 1843 (Mio-Pliocene pinniped *Imagotaria*)
S 1220 (controversy over diphyly in pinnipeds)
1240 (NE Pac. stranding distribution & seasonality of *Ziphius cavirostris*)
A 107 (N Atl. whale research)

Mollusca (*see also* subclassifications; *also* names of individual species, e.g. Clam, Mussel, Oyster, Scallop; Shipworms; Squid)
J 25(9): 1803 (caloric content of several species)
CNG 84 (popular description of some NE Pac. Ocean)
T 2 (distributional checklist & bibliography of Canada W coast marine)

Molting (*see* Moulting)

Monochrysis lutheri (a marine planktonic alga)
S 1248 (characterization of phospholipase from)

Monogenea (*see* Tapeworms)

Moonfish (*see* Panpano)

Morley, Ronald Bruce
J 25(12): 2695 (sockeye & pink salmon chilled ova & sperm)

Morphology; Morphometry (*see also* Length; Size; *also* names of organisms, organs, and tissues: *also* Cytology; Histology)
J 25(1): 101 (of white & largescale suckers re hybridization)
(1): 181 (*Macdonaldia challengeri* tapirfish)
(2): 321 (Chondracanthidae parasitic copepods)
(2): 421 (longnose greeneye)
(3): 439 (laboratory-reared blue king crab larvae)
(3): 541 (*Polinices* podium re expansion & locomotion)
(4): 813 (sexual dimorphism in trouts anal fins)
(5): 877 (*Halargyreus johnsonii*)
(5): 943 (N American Atl. & artic coast *Anonyx* Amphipoda)
(5): 1075 (NW Atl. pelagic stingray)
(8): 1637 (*Cyphocaris bouvieri* amphipod)
(9): 1775 (N.S. offshore sand launce)
(9): 1923 (*Caligus curtus* parasitic copepod)
(11): 2365 (2 new species of *Gyrocotyle* tapeworms)
(11): 2403 (changes during parr–smolt coho salmon transformation)
B 162 : 378 (re sockeye salmon stocks identification)
T 34 (arrowtooth & spinycheek flounder; rock & flathead sole; Pac. cod)

Morrison, Carol Marianne
J 25(7): 1339 (scallop striated muscle)

Mortality (*see also* Disease; Insecticides; Predation)
J 25(1): 81 (of trouts & shiners re limnology of 3 SW B.C. lakes)
(3): 473 (after stress in salmons)
(3): 555 (rates of S Gulf of St. Lawrence cod population)
(4): 757 (marine, of pink salmon: mathematical treatment)

(6): 1145 (re angling harvest of maskinonge in 2 Ont. lakes)
(6): 1219 (estimation theory for Bristol Bay sockeye salmon oceanic)
(6): 1291 (re age of exploitation: mathematical treatment)
(7): 1359 (& survival re walleye exploitation in Nipigon Bay fishery, Ont.)
(8): 1733 (of commercially caught spider crabs)
(10): 2091 (lake whitefish, Lac la Ronge, Sask.)
(10): 2169 (kinds of, experienced by Atl. salmon, Little Codroy R., Nfld.)
(11): 2467 (from fungus attack on chinook salmon)
B 162: 67, 83, 131, 145, 365, 371 (sockeye salmon during life history stages)
A 108 (1966 Canadian ICNAF studies on Atl. seals & various Atl. fishes)

Motella tricerratus (*see* Onos)

Moulting
J 25(9): 1763 (adverse conditions affecting lobster)
(10): 2251 (delay of lobster larvae)

Mounib, M. Said
J 25(12): 2623 (Atl. cod sperm preservation)
S 1231 (cod sperm uricolytic enzymes)
1236 (lipid biosynthesis by salmon sperm)
1237 (carbon dioxide fixation by cod spermatozoa)

Movements (*see* Behaviour; Marking; Migration; Tagging)

Mudminnow, central (*Umbra limi*)
J 25(6): 1199 (low temperature effects on feeding in 3 Ont. localities)

Mudpuppy (*Necturus maculosus*)
S 1226 (fatty acids positional distribution in triglycerides)

Mugil cephalus (*see* Chub)

Mugil cunnesius (a tropical mullet)
J 25(1): 197 (microorganisms isolated from diseased)

Mullet (a tropical) (*see Mugil cunnesis*)

Mummichog (*Fundulus heteroclitus*)
J 25(8): 1739 (spinal ganglia position re taxonomy)
(12): 2717 (upper lethal temperatures at various salinities after isosmotic acclimation)

Murray, Alan Roderick
J 25(10): 2165 (salmon from Little Codroy R., Nfld.)
T 38 (Little Codroy R., Nfld., salmon counting fence)
84 (Atl. salmon & brook trout at Little Codroy R., Nfld., 1954–63)
S 1257 (counting fence for Atl. salmon)

Muscle (*see also* Fillets; Myosin; Protein; Quality)
J 25(2): 239 (adenine nucleotide degradation products as quality criteria in chilled fresh & thawed mackerel)
(4): 738 (lactate, glycogen, & *p*H of Atl. cod, after freezing)
(5): 837 (lactic acid and glycogen of Atl. cod, after exercise)
(6): 1247 (white skeletal of Pac. salmons re transaminases activity)
(7): 1317 (proteins inheritance in redside shiner × peamouth chub hybrids)
(7): 1339 (ultrastructure of scallop striated)
(7): 1475 (tripolyphosphate dip to reduce drip loss)
(8): 1525 (quantitative glycogen & Δ7P extraction from frozen cod)
(8): 1539 (postmortem degradation in fish)
(8): 1555 (starvation effect on rainbow trout free fatty acids)
(8): 1581 (2 forms of malic enzyme in fish muscle sarcoplasm)
(9): 1797 (dieldrin accumulation in goldfish, after aldrin ingestion)
(9): 1987 (temperature of recently caught marlin, etc. red & white)
(10): 2059 (protein extractability re free fatty acids in iced cod)
(10): 2157 (dissolution of homogenates, by lysolecithin)
(11): 2461 (accumulation of natural ^{65}Zn in crustacean)
(12): 2711, 2715 (fish muscle creatine kinase)
S 1224 (hormone conversion by lobster)
1261 (adenine nucleotides postmortem degradation in lobster)

Mussel, bay (Atlantic) (*Mytilus edulis*) blue mussel)
J 25(2): 267 (occurrence & retention of thetin derivative from feed)

Mussel, blue (*see* Mussel, bay (Atlantic))

Mussel, freshwater (*Anodonta californiensis*)
J 25(12): 2691 (^{65}Zn metabolism)

Mussel, horse (*Volsella modiolus*)
J 25(2): 267 (occurrence & retention of thetin derivative from feed)

Abbreviations: J — Journal; B — Bulletin; AR — Annual Report; R — Review; *Circular series*: CDG — Dartmouth; CHN — Halifax; CJG — St. John's; CNG, CNS — Nanaimo; CSG — St. Andrews; CVG — Vancouver; T — Technical Reports; MSP — Miscellaneous Special Publications; S — Studies; A — Interpretive Articles.

Mussel, ribbed (*Volsella demissa*)
J 25(2): 267 (occurrence & retention of thetin derivative from feed)

Mustela vison (*see* Mink)

Mya arenaria (*see* Clam, soft-shell)

Mycteroperca bonaci (*see* Grouper, black)

Mycteroperca venenosa (*see* Grouper, yellowfin)

Myctophidae (*see* Lanternfishes)

Muth, Kenneth Maxwell
J 25(1): 1 (hatchery-reared & wild salmon behavior)

Mylocheilus caurinum (*see* Chub, peamouth)

Myosin (*see also* Muscle)
S 1195 (reaction with malonaldehyde re trout muscle denaturation)

Myoxocephalus polyacanthocephalus (*see* Sculpin, great)

Myoxocephalus thompsonii (*see* Sculpin, deepwater)

Mysidacea (*see also* subclassifications)
T 55: 93 (identification of B.C.)

Mytilus edulis (*see* Mussel, bay (Atlantic))

N

Nakano, Tomoo
J 25(3): 603 (addendum: trout catecholamine & carbohydrate concentrations)

Nakatani, Roy Eiji
J 25(3): 591 (growth on metabolite retention time)
(12): 2691 (^{65}Zn in freshwater mussel)

Nansenia candida (*see* Argentines)

Narver, David Wells
J 25(1): 157 (*Mesidotea entomon* in Alaska)

Nass River, B.C. (*see also* Salmon)
S 1230 (spawning populations of sockeye & other salmons)

Neal, Wanda Eloise
J 25(5): 921 (frozen cod muscle TMA)

Nealotus tripes (a gempylid fish)
J 25(5): 916 (X-ray showing effect of attack by swordfish)

Neate, Harry
S 1262 (gear for electrofishing coho)

Necturus maculosus (*see* Mudpuppy)

Nelson, Joseph Schieser
J 25(1): 101 (*Catostomus commersonii* & *C. macrocheilus* hybridization & isolating mechanisms)
(2): 409 (N American kokanee distribution & nomenclature)
(2): 415 (N American kokanee gillraker variation)

Nematoda (*see also* Codworm)
B 162: 94, 378 (*Dacnitis truttae* & *Philonema oncorhynchi* re sockeye salmon stocks identification)
T 43 (on Irish moss)
48 (parasitic to lampreys)
S 1206 (*Anisakis* parasitic in Atl. salmon liver)
1255 (*Contracaecum* parasitic in capelin)

Nemertea
T 25, 35, 59, 60, 73 (in Strait of Georgia benthos biomass)

Nemichthys avocetta (*see* Threadfish)

Nemoura (*see* Stoneflies)

Neoscopelarchoides dentatus (*see* Pearleye, northern)

Nerve system
J 25(8): 1739 (taxonomic correlation of spinal ganglia position in teleosts)
(9): 1797 (dieldrin accumulation in goldfish spinal cord after aldrin ingestion)
(12): 2677 (DDT effect on brook trout lateral line response)

Net, gill
J 25(5): 935 (skeletal muscle chemistry of Atl. cod caught by)

Nets (*see also* Gear; Fishing methods; Trawl)
J 25(6): 1161 (for sampling tidewater Atl. herring larvae)
B 162 : 219, 220 (plankton)
T 33 (Great Slave L. winter fishery)
37 (selection for coastal zooplankton observations)
38 (estuarine, for trapping Atl. salmon)
S 1257 (estuarine, for trapping Atl. salmon)

New Brunswick (*see also* Miramichi River)
B 166 : 48 (eel fishery)
T 6 (evaluating forest spraying effects on salmon)
A 83 (effects of DDT forest spraying residues on salmon)

Newfoundland (*see also* International Commission for the Northwest Atlantic Fisheries; Labrador)
J 25(4): 733 (quality of trap-caught cod after freezing)
(10): 2165 (Atl. salmon smolt survival & adult utilization, Little Codroy R.)

(12): 2723 (lobsters in deep water off St. John's)
B 166 : 45 (eel fishery)
CJG 14,15 (fishery investigations & groundfish landings, 1966, 1967)
T 43 (Irish moss ecology)
S 1216 (sea & air temperature anomalies)
A 95 (recent investigations of Atl. herring)
106, 108, 113 (history & success of pink salmon egg transplants from Pac. coast)

Niacin (*see* Vitamin B group)

Nickel compounds
J 25(4): 639 (re marine flesh oxidative rancidity)

Nipigon Bay, Ont.
J 25(7): 1347 (dynamics & exploitation of mature walleyes)

Nigrelli, Ross Franco
J 25(3): 597 (yellowtail flounder *Ichthyophonus* infection)

Nitrate (*see also* Limnology; Oceanography)
J 25(6): 1229 (re phytoplankton ecology in an Ont. reservoir)
(10): 2101 (utilization in subarctic lake)
B 167 : 71, 125 (determination in sea water)
S 1223 (re marine benthos feed)

Nitrite
B 167 : 77, 129 (determination in sea water)

Nitrogen compounds (*see also* types of)
J 25(10): 2101 (N fixation & other inorganic N sources in subarctic lake)
B 167 : 71, 77, 81, 87, 119, 143, 221 (determination in sea water)
S 1198 (requirements for *Hemiselmis virescens* phototrophic growth)
1223 (particulate, re marine benthos feed)

Nocardia asteroides (bacteria)
J 25(2): 423 (causing nocardiosis of brook trout)

Noise (*see* Sound, reactions to)

Nomenclature
J 25(2): 409 (& distribution of N American kokanee)
(11): 2269 (arctic Canada Bryozoa)
T 2 (synonymy of Canada W coast Mollusca)
34 (arrowtooth & spinycheek flounder; rock & flathead sole; Pac. cod)
S 1219 (Polychaeta (Errantia) recorded from B.C. since 1923)
1243 (Polychaeta (Sedentaria) recorded from B.C. since 1923)

North Harbour River, Nfld.
CJG 14 : 32; 15: 24 (increasing establishment of pink salmon from B.C.)
A 106 (success of pink salmon eggs transplants from B.C.)
108 : 12 (1966 Canadian ICNAF report on above)
113 (review of pink salmon egg transplants from B.C.)

Northwest Territories, Canada
J 25(12): 2575 (physics & chemistry of some fresh waters)

Norwegian Sea (*see* Oceanography, Norwegian Sea)

Nota, Dirk Johannes Gregorius
J 25(11): 2327 (St. Lawrence R. estuary minerals)

Notemigonus crysoleucas (*see* Shiner, golden)

Notolepis rissoi rissoi (*see* Barracudina, ribbon)

Notropis atherinoides (*see* Shiner, emerald)

Notropis cornutus (*see* Shiner, common)

Nova Scotia (*see also* Sable Island; *also* names of specific localities)
J 25(2): 427 (lobster larvae distribution off Pictou)
B 166 : 45 (eel fishery)

Nova Scotia Banks
T 80 (fish stocks)

Nowlan, Sandra Simpson
J 25(8): 1525 (frozen cod muscle glycogen & phosphorus)

Nucleosides; Nucleotides (*see also* Acids, nucleic)
J 25(2): 239 (adenine nucleotides degradation products as quality criteria for chilled mackerel muscle)
(4): 817 (nucleotide degradation in iced redfish fillets)
(8): 1667 (re cytotaxonomy of Great Lakes coregonids)
S 1246 (nucleoside-3′,5′ cyclic phosphates synthesis)
1247 (nucleotide *p*-nitrophenyl & 2,4-dinitrophenyl esters)
1261 (adenine nucleotides postmortem degradation in lobster)

Nutrition value (*see also* Composition, chemical; Productivity, primary; Vitamin B group)
J 25(9): 1803 (caloric content of marine benthic & epibenthic invertebrates)

(11): 2515 (caloric content of some freshwater invertebrates)
B 167 : 119, 139, 175 (determination methods for sea water)
A 80 (general, re various quality changes & flavour)
97, 98 (herring & Atl. cod products & by-products)

O

Occa verrucosa (*see* Poacher, warty)

Oceanography, B.C. coast (*see also* Georgia, Strait of; Oceanography, north Pacific Ocean)
J 25(3): 457 (sound-scattering layers re mid-water trawl catches)
R 1965–1966: 105 (review of Board investigations)
T 32, 82 (surface temperatures & salinities, 1965, 1966)
70 (central region)

Oceanography, Canadian and U.S. Atlantic coast (*see also* Hydrography)
J 25(5): 1079 (inertial oscillation at lat 42°N)
(11): 2427 (Gulf of Maine subsurface waters recent temperature trends)
(12): 2609 (summer stratifications & mixing, Gulf of Maine)
R 1965–1966: 39 (review of Board investigations)
T 26 (1965 summer observations, S Gulf of St. Lawrence)
77 (St. Margaret's Bay, N.S., re primary productivity)
S 1215 (recent sea temperature changes)
1216 (sea vs. air temperature anomalies)
A 82 (F) (marine climate, Gulf of St. Lawrence & to SW)
92 (abnormal sea temperatures effect on herring fishery)
108 (1966 Canadian ICNAF studies on temperature, salinity, currents, etc.)

Oceanography, general (*see also* Currents; Hydrography; Tides)
B 167 (practical handbook of seawater analysis)
S 1234 (H_2O–NaCl–Na_2SO_4 system isopiestic measurements)

Oceanography, North Pacific Ocean (*see also* Bering Sea)
J 25(12): 2739 (surface phosphate & silicate distribution in NE)
B 162 : 329 (re sockeye salmon marine life & distribution)
R 1965–1966 (review of Board investigations)
T 50, 51, 52, 63, 64, 65, 66 (surface transport charts, 1946–67)
53 (transport computations)
54 (temperatures & salinities, 1965, 1966)
75 (central subarctic region, winter 1966)
A 86 (1966 temperatures & salinity in NE region re salmons research)

Oceanography, Norwegian Sea
T 71, 72 (transport computations, 1950–60)

O'Connell, David Thomas
J 25(1): 189 (Atl. fish DDT residues

Octopus (*Octopus apollyon*)
T 7, 56 (in B.C. commercial trawling)

Ocyurus chrysurus (*see* Snapper, yellowtail)

Odense, Paul Holger
J 25(4): 805 (FPC isopropyl alcohol retention)
(5): 935 (cod skeletal muscle FAA re gillnet fishing)
(7): 1339 (scallop striated muscle)

Odobenus rosmarus rosmarus (*see* Walrus, Atlantic)

Odours (*see also* Quality of fish products)
J 25(4): 639 (developed by metal-induced oxidative rancidity of marine flesh)
(10): 2071 (developed in untreated & EDTA-treated haddock fillets)
(11): 2453 (dimethyl sulphide, in soft-shell clams)
CVG 39 (suppression in fishmeal production)
A 112 (same as CVG 39 above)

Odours, reaction to
J 25(5): 867 (of chinook salmon re choosing spawning site)

Ogilvie, J. M.
J 25(7): 1475 (cod muscle polyphosphates)

Oils and fats, aquatic animal (*see also* Acids, fatty; Liver (oils); Lipases)
J 25(1): 169 (pesticide residues in freshwater fish)
(11): 2419 (harp & hooded seal depot fat & commercial seal oils fatty acids composition)
CVG 38 (recovery by clarifying salmon-canning waste-waters)
T 5 (fatness condition of Atl. herring)
A 98 (Atl. herring)

Olfactory perception and response (*see* Odours, reaction to)

Oligochaeta
T 43 (on Irish moss)

Omnastrephes sloani pacificus (*see* Squid)

Oncorhynchus gorbuscha (*see* Salmon, pink)

Oncorhynchus keta (*see* Salmon, chum)

Oncorhynchus kisutch (*see* Salmon, coho)

Oncorhynchus masou (*see* Masu)

Oncorhynchus nerka (*see* Salmon, sockeye; *also* Kokanee)

Oncorhynchus rhodurus (*see* Salmon, redspot)

Oncorhynchus tshawytscha (*see* Salmon, chinook)

Oneirodes acanthias (*see* Dreamers)

Oneirodes eschrichti-group (*see* Dreamers)

Onos (*Motella tricerratus*)
J 25(12): 2711 (muscle creatine kinase localization)

Ontario (*see also* Great Lakes; *also* names of the individual Great Lakes)
J 25(2): 285; (6): 1133 (L. Opinicon fishes feeding habits)
(6): 1145 (Pigeon & Sturgeon L. maskinonge mortality re angling)
(6): 1199 (fishes feeding habits in Fish L. & 2 creeks)
(6): 1229 (L. Belwood reservoir phytoplankton ecology)
(7): 1347 (walleye exploitation & dynamics in Nipigon Bay)
B 166 : 52 (eel fishery)

Ontario, Lake (*see also* Great Lakes)
A 106 (transplants of *Oncorhynchus* salmons into)

Oozy Creek, P.E.I.
T 3 (biotic survey)

Ophel, Ivan Lindsay
J 25(7): 1333 (marking fish with stable strontium)

Ophiodon elongatus (*see* Lingcod)

Ophiuroidea (*see also* Starfish)
T 25, 35, 59, 60, 73 (in Strait of Georgia benthos biomass)

Opinicon, Lake, Ont.
J 25(2): 285 (feeding biology of black crappie & associates)
(6): 1133 (diel feeding habits of 5 species of fish)

Opisthobranchiata
T 2 (distributional checklist & bibliography of B.C. marine)

Opsanus tau (*see* Toadfish, oyster)

Oregon
J 25(12): 2665 (species associations of coastal benthic fishes)

Oregonia gracilis (*see* Crabs, spider)

Organolepsis (*see* Light, reactions to; Odours, reactions to; Quality; Salinity, reactions to; Sound, reactions to)

Organoleptic tests (*see* Quality of fishery products)

Orientation
J 25(10): 2123 (of sea scallop on bottom & swimming when disturbed)
(10): 2143 (of adult American eel towards spawning area)

Oscillation, tidal or current (*see* Currents; Tides)

Oscillatoria species (*see also* Phytoplankton)
J 25(6): 1229 (in phytoplankton ecology of an Ont. reservoir)

Osmerus eperlanus mordax (*see* Smelt, "giant" and "dwarf")

Osmotic coefficient
S 1234 (of H_2O–NaCl–Na_2SO_4 system re sea water)

Osteology
J 25(9): 1843 (of new genus & species of fossil sea lion)
S 1240 (skulls of stranded Cuvier's beaked whales)

Osterberg, Charles Lamar
J 25(11): 2461 (^{65}Zn in marine crustaceans)

Ostracoda
T 25, 35, 59, 69, 73 (in Strait of Georgia benthos biomass)
55 : 31 (identification of B.C.)

Ostrea Lake, N.S. (tidal)
T 76 (pre-fertilization benthic survey)

Otariidae (*see also* Sea lion)
J 25(9): 1843 (subfamilies, tribes, & genera classification)

Otoliths (for fish age determination) (*see also* Age)
J 25(5): 1067 (vs. scales for sockeye & chum salmon)
(11): 2503 (abnormal growth of Atl. herring)
(12): 2561 (of fish in cetacean stomachs re latter's feeding habits)
T 27 (Atl. cod)
31 (Atl. mackerel)
49 (Atl. herring)
74 (vs. scales for sablefish)

Abbreviations: J — Journal; B — Bulletin; AR — Annual Report; R — Review; *Circular series*: CDG — Dartmouth; CHN — Halifax; CJG — St. John's; CNG, CNS — Nanaimo; CSG — St. Andrews; CVG — Vancouver; T — Technical Reports; MSP — Miscellaneous Special Publications; S — Studies; A — Interpretive Articles.

S 1208 (reliability for Atl. cod)
1212 (witch flounder)
1255 (re NW Atl. capelin)
A 108 : 19 (Atl. hake)

Ouareau, Lake, Que.
J 25(9): 1831 (F) (maskinonge age & growth)

Outram, Donald Noel
CNG 86 (1968 herring spawn in B.C. waters)
A 102 (herring spawning less than half average)

Ova (*see* Eggs)

Ovary (*see also* Eggs)
J 25(6): 1299 (re ova density in winter flounder)
(9): 1797 (dieldrin accumulation in goldfish, after aldrin ingestion)
(9): 1813 (F) (to body weights of "giant" vs. "dwarf" smelts)
(12): 2643 (furunculosis bacteria in brook trout)

Owens, Eben Lowell
J 25(11): 2519 (fish-marking technique)

Owikeno Lake, B.C.
B 162 (re B.C. sockeye salmon studies)

Oxygen, dissolved (*see also* Hydrography; Limnology; Oceanography; Respiration)
J 25(1): 49 (effect on swimming speed of juvenile largemouth bass & coho salmon)
(1): 81 (artificial vertical circulation effect on, in eutrophic lakes)
(3): 579 (effects of diurnal fluctuations on brook trout growth)
(6): 1229 (re phytoplankton ecology in an Ont. reservoir)
B 167 : 21, 263 (determination in sea water)

Oxylebius pictus (*see* Greenling, painted)

Oyster, Atlantic (*Crassostrea virginica*)
J 25(2): 267 (occurrence & retention of thetin derivative in feed)
(4): 639 (catalysis of flesh oxidative rancidity by metal ions)
(11): 2521 (association with a microturbellarian)
B 131 (French edition of 1961 original English edition on culture of, in Canadian Maritime Provinces. See Bulletin 164 for complete indexing.)
CDG 1 (eelgrass control on beds)
S 1198 (ancient shells on Sable Is., N.S.)
1210 (re use of eelgrass herbicide)
1215 (hemolymph hemagglutinins)
A 84 (effect of various pollutants on productivity)
109 (same as CDG 1 above)

P

Pacific Ocean (*see also* Oceanography, B.C. coast; Oceanography, North Pacific Ocean)
CNG 84 (guide to zooplankton of NE)

Pagophilus groenlandicus (*see* Seal, harp)

Pagurus (species) (*see* Crab, hermit)

Paim, Uno
J 25(11): 2321 (DDT degradation in Atl. salmon)

Paints
CSG 52 (antifouling coatings for boats)
53 (for protection against woodborers)
A 88 (same as CSG 52 above)
114 (same as CSG 53 above)

Paloheimo, Jyri Erkki
J 25(3): 555 (Gulf of St. Lawrence cod)

Pancreas (*see also* Hepatopancreas)
J 25(2): 383 (infectious pancreatic necrosis in young trout)
S 1224 (conversion of androstenedione to testosterone by lobster hepatopancreas)
1250 (pancreatic lipase substrate specificity)

Pandalopsis dispar (*see* Shrimp, sidestripe)

Pandalus borealis (*see* Shrimp, pink)

Pandalus hypsinotus (*see* Shrimp, humpback)

Pandalus jordani (*see* Shrimp, smooth pink)

Pandalus montagui (*see* Shrimp, striped pink)

Pandalus platyceros (*see* Prawn)

Panpano (*Trachinotus ovatus*) (moonfish)
J 25(1): 197 (microorganisms isolated from diseased)

Pantothenic acid (*see* Vitamin B group)

Paralithodes camtschatica (*see* Crab, king)

Paralithodes platypus (*see* Crab, blue king)

Parasites; Parasitism (*see also* Disease)
J 25(2): 321 (Chondracanthidae copepoda on B.C. fishes)
(6): 1161 (*Hemioniscus balani* isopod in barnacles)
(9): 1923 (review & description of *Caligus curtus* copepod)
(10): 2241 (*Amoebophyra* dinoflagellate on *Gonyaulax* dinoflagellate)
(11): 2467 (*Dermocystidium* fungus on chinook salmon)

(11): 2365 (2 new *Gyrocotyle* tapeworms from deepwater chimaera)
(11): 2521 (microturbellarian association with Atl. oyster)
B 162 : 94, 378 (re sockeye salmon stocks identification)
T 42 (clam drill on B.C. clams)
48 (of lamprey species)
81 (copepod, of Pac. turbot)
83 (bibliography of Atl. salmon)
S 1206 (of salmon in Labrador Sea & off W Greenland)
1255 (of NW Atl. capelin)
A 108: 17 (of *Sagitta elegans*)

Parasudis truculentus (*see* Greeneye, longnose)

Paricelinus hopliticus (*see* Sculpin, thornback)

Park, Paul Kilho
J 25(12): 2739 (NE Pac. phosphate & silicate distribution)

Parker, Robert Ray
J 25(4): 757 (Bella Coola R. pink salmon mortality schedules)
(9): 1923 (*Caligus curtus* parasitic copepod
T 17 (micromagnetic tags to pink salmon fry)

Parks, M. J.
T 3 (Oozy Creek, P.E.I. biotic survey)

Parophrys vetulus (*see* Sole, English)

Parr (*see* Salmon, Atlantic; *also* species of Pacific salmons)

Parsons, Timothy Richard
B 167 (seawater analysis handbook)
S 1223 (food availability seasonal variations for benthos)

Particulate matter (*see* Matter, particulate)

Pastes, fish
CHN 32 (Japanese frozen minced fish)

Pasteurization (*see* Irradiation)

Pathogens (*see* Bacteria; Disease)

Pathological conditions (*see* Disease)

Pauley, Gilbert Buckhannan
J 25(11): 2467 (chinook mortality re *Dermocystidium*)
(12): 2691 (^{65}Zn in freshwater mussel)

Pearcy, William Gordon
J 25(7): 1311 (pressure re crustacean respiration)
(12): 2665 (species associations off oregon)

Pearleye, northern (*Neoscopelarchoides dentatus*)
T 11 (in experimental B.C. midwater trawling)

Pecten (*Cyclopecten carlottensis*)
J 25(7): 1509 (new species from NE Pac.)

Peden, Alex Edward
J 25(1): 181 (*Macdonaldia challengeri* in E N Pac. Ocean)
T 34 (N Pac. Ocean systematics of 6 demersal fishes)

Peer, Donald Lloyd
J 25(9): 1803 (invertebrate caloric content)

Pelecypoda (*see also* subclassifications)
T 2 (distributional checklist & bibliography of B.C. marine)
25, 35, 59, 60, 73 (in Strait of Georgia benthos biomass)
43 (on Irish moss)
76 (in tidal Ostrea L., N.S.)

Peppar, John Lovell
T 34 (N Pac. Ocean systematics of 6 demersal fishes)

Perca flavescens (*see* Perch, yellow)

Perch, Pacific ocean (*Sebastodes alutus*) (longjaw rockfish)
J 25(2): 329 (host to parasitic Chondracanthid copepod)
(3): 457 (in B.C. midwater trawl catches)
(11): 2477 (proteins electropherograms re rockfishes systematics)
(12): 2665 (associations with other fishes off Oregon coast)
T 7, 11, 19, 22, 30, 46, 56, 52, 81, 89 (in B.C. experimental or commercial trawling)
16 (catch rate, size composition, & sex ratio of experimental NE Pac. catches, 1966)
81 (size composition, W coast Vancouver Is.)
A 90, 103 (fishery trend along N America coast)
91 (1956 & 1966 B.C. landings for mink feed)

Perch, pile (*Rhocochilus vacca*) (pile seaperch)
J 25(8): 1651 (plasma protein-bound inorganic iodide)
T 7, 56, 81 (in experimental or commercial B.C. trawling)
A 91 (observed in B.C. landings of fish for mink feed)

Perch, shiner (*Cymatogaster aggregata*) (shiner seaperch)

J 25(12): 2665 (associations with other Oregon coast fishes)
T 7, 11, 22, 56, 62 (in experimental or commercial B.C. trawling)
A 91 (observed in B.C. landings of fish for mink feed)

Perch, white (*Roccus americanus*)
J 25(6): 1199 (low temperature effects on feeding in 3 Ont. localities)
(10): 2225 (reproduction in Bay of Quinte, L. Ontario)

Perch, yellow (*Perca flavescens*)
J 25(4): 667 (re Great Lakes species succession & exploitation)
(4): 711 (seasonal effect on schooling behaviour)
(6): 1133 (diel feeding habits)
(6): 1199 (low temperature effects on feeding in 3 Ont. localities)
(8): 1651 (plasma protein-bound inorganic iodide)
(8): 1739 (spinal ganglia position re taxonomy)

Percopsis omiscomaycus (*see* Trout-perch)

Peridinium aciculiferum (*see also* Phytoplankton)
J 25(6): 1229 (in phytoplankton ecology of an Ont. reservoir)

Periplaneta americana (*see* Cockroach)

Periwinkle, common (*Littorina littorea*)
J 25(2): 267 (occurrence & retention of thetin derivative from feed)
S 1226 (fatty acids positional distribution in triglycerides)

Pesticides (*see also* Fungicides; Herbicides; Insecticides; Pollution; Toxicants)
J 25(1): 169 (residues in freshwater fishmeals & oils)
A 81 (chemical methods of assaying for residues)
83 (criteria for effects of residues (DDT) on Atl. salmon)
87 (biological methods of assaying for residues)

Peters, John Anthony
J 25(2): 299 (refrozen cod storage quality)

Petromyzon marinus (*see* Lamprey, sea)

*p*H (*see also* Limnology; Oceanography)
J 25(1): 15 (re blood lactic acidosis of channel catfish in anoxia)
(1): 33 (of SW B.C. streams)
(4): 738 (of trap-caught Atl. cod before & after freezing)
(6): 1229 (re phytoplankton ecology in an Ont. reservoir)
B 167 : 27, 295–302 (determinations re seawater analyses)

Philonema oncorhynchi (*see* Nematoda)

Phinney, Duane Earl
J 25(1): 203 (surf smelt W range extension)

Phoca vitulina concolor (*see* Seal, harbour (western Atlantic))

Phoca vitulina richardi (*see* Seal, harbour (eastern Pacific))

Phocanema decipiens (*see* Codworm)

Phocoena sinus (*see* Dolphin, Gulf of California harbour)

Phoronidea
T 35 (in Strait of Georgia benthos biomass)

Phosphamidon (*see* Insecticides)

Phosphates (*see also* Limnology; Oceanography)
J 25(6): 1229 (re phytoplankton ecology in an Ont. reservoir)
(7): 1475 (weight changes in Atl. cod muscle dipped in Na tripolyphosphate solutions)
(8): 1571 (degradation of toxicant, by fish liver phosphatases)
(12): 2739 (NE Pac. Ocean surface distributions)
B 162 : 200 (as nutrient in sockeye salmon lakes)
167 : 63, 135, 139, 245 (& polyphosphates, determination in sea water)
S 1246 (nucleoside-3′,5′ cyclic phosphates synthesis)
A 85 (in freshwater fishmeals)

Phospholipids
S 1227 (fatty acids composition in fin whale milk)
1233 (marine fatty acids incorporation into rat & mink)
1248 (phospholipase C from a marine planktonic alga)

Phosphorus compounds (*see also* Nucleosides; Phosphates; Phospholipids)
J 25(8): 1525 (quantitative extraction from frozen Atl. cod muscle)
B 167 : 45–57, 141, 219 (determination of reactive & particulate in sea water)

Photoperiod effects (*see* Light, reactions to)

Photosynthesis (*see also* Algae; Chlorophylls; Phytoplankton; Plankton; Productivity, primary; Thetin derivatives)
J 25(4): 625 (re production of marine bacteria)
B 167 : 261 (rate determination in sea water)
S 1198 (N compound requirements for *Hemiselmis virescens* growth)

Phrixocephalus cincinnatus (parasitic copepod)
T 81 (on turbot)

Phylogeny
J 25(9): 1843 (Pinnipedia: Otariidae)
B 162 : 4 (sockeye salmon)
S 1197 (of marine planktonic algae)
1220 (controversy over diphyly in Pinnipedia)

Physeter catodon (*see* Whale, sperm)

Physiology (*see also* aspects of)
J 25(9): 1983 (rainbow trout undergoing thermal stress)

Phytanic acid (*see* Acids, fatty)

Phytoplankton (*see also* Algae; Chlorophylls; Feed; Plankton; Production, primary)
J 25(6): 1229 (ecology in L. Belwood reservoir, Ont.)
(6): 1269 (generation of starch in ocean waters)
(8): 1603 (fatty acids of marine)
(8): 1749 (associated with Gulf of Maine red water bloom)
(10): 2219 (loss of radioactivity of ^{14}C-labelled stored on filters)
T 77 (biomass re primary productivity, St. Margaret's Bay, N.S.)
S 1223 (re seasonal variations in marine benthos feed availability)
1254 (chlorophyll as possible precursor of shale isoprenoid fatty acids)

Pickerel, grass (*Esox americanus vermiculatus*)
J 25(6): 1199 (low temperature effects on feeding in 3 Ont. localities)

Pickerel, yellow (*see* Walleye)

Pienaar, Leon Visser
J 25(12): 2743 (mean weight from length statistics)
T 40 (multiple discriminant analysis program)
50 (surface transport charts N Pac. Ocean, 1946–49)
51 (surface transport charts N Pac. Ocean, 1963–66)
52 (surface transport charts N Pac. Ocean, 1967)
63 (surface transport charts N Pac. Ocean 1950–52)
64 (surface transport charts N Pac. Ocean 1953–55)
65 (surface transport charts N Pac. Ocean 1956–58)
66 (surface transport charts N Pac. Ocean 1959–62)

Pig
S 1203 (positional distribution of monoenoic fatty acids in bacon & mesenteric triglycerides)

Pigeon Lake, Ont.
J 25(6): 1145 (maskinonge angling harvest re mortality)

Pigments; Pigmentation (*see also* Chlorophylls)
J 25(3): 611 (guanidine compounds induction of skin pallor in salmonids)
(4): 801 (of early larval canary rockfish)
(10): 2233 (fluorescent, for tattooing fingerling salmonids)
B 167 : 185 (carotenoids & chlorophylls determination in seawater)

Pike, northern (*Esox lucius*)
J 25(8): 1651 (plasma protein-bound inorganic iodide)
(12): 2711 (muscle creatine kinase localization)
T 33 (in Great Slave L. fishery)

Pilchard (*see* Sardine, California)

Pilot plant
CVG 39 (for fishmeal research)
A 112 (same as CVG 39 above)

Pimephales promelas (*see* Minnow, fathead)

Pinnipedia (*see also* Sea lion: Seal; Walrus)
J 25(9): 1843 (new genus of Mio-Pliocene period)
S 1220 (controversy over diphyly)

Pippy, John Herbert Charles
T 83 (bibliography on Atl. salmon parasites & diseases)

Pirson, Jacques Émile
J 25(12): 2739 (NE Pac. phosphate & silicate distribution)

Pitotmeter
B 163 : 17 (for measuring forces exerted on otter trawl)

Pitt, Thomas Kenton
S 1207 (American plaice catches diurnal variation)

Pitts, Dianne Paulette
J 25(2): 239 (mackerel muscle nucleotide degradation)

Pituitary
J 25(7): 1465 (metopirone effect on pituitary–interrenal function of sockeye salmon & rainbow trout)

(7): 1497 (hypophysectomy effect & relief in goldfish by chinook salmon pituitary extract)
S 1245 (extract promoting protamine biosynthesis in steelhead trout)
1249 (hypophysectomized goldfish spermiation as bioassay for salmon gonadotropin)

Placopecten magellanicus (*see* Scallop, giant)

Plaice (European) (*Pleuronectes platessa*)
J 25(4): 717 (mathematical treatment of growth & feeding)

Plaice, American (*Hippoglossoides platessoides*)
J 25(4): 639 (catalysis of flesh oxidative rancidity by metal ions)
(4): 829 (thaw drip variations in fillets)
CJG 14 (Nfld. landings, 1966)
15 (Nfld. landings, 1952–67)
T 80 (stocks, Gulf of St. Lawrence & N.S. Banks)
S 1207 (diurnal variation in catches from Grand Bank)
1213 (length–weight relations in ICNAF Subarea 4)
A 108 (1966 Canadian ICNAF studies: commercial catches; spawning; maturity; growth; age)

Plankton (*see also* Algae; Feed; Phytoplankton; Zooplankton)
J 25(8): 1741 (sampling pipe used on frozen lakes)
B 162 : 205, 224, 254, 346 (re sockeye salmon feed in lakes & sea)

Plasma (*see* Blood)

Platford, Robert Frederick
S 1234 (H_2O–NaCl–Na_2SO_4 isopiestic measurements at 25°C)

Platichthys stellatus (*see* Flounder, starry)

Platt, Trevor
T 77 (St. Margaret's Bay primary production 1967)

Platyhelminthes (*see* Tapeworms)

Plecoptera (*see* Stoneflies)

Plectobranchus evides (*see* Prickleback, black-and-white)

Pletcher, Ferdinand Tony
J 25(10): 2237 (subcutaneous dart tag for fish)
T 74 (1964–65 sablefish study)

Pleurogrammus azonus; *P. monopterygius* (*see* Mackerel, Atka)

Pleuronectes platessa (*see* Plaice (European))

Pleuronichthys coenosus (*see* Sole, C–O)

Pleuronichthys decurrens (*see* Sole, curlfin)

Plotosus anguillaris (*see* Eel, barbel)

Poacher, blackfin (*Bathyagonus nigripinnis*)
J 25(12): 2665 (associations with other fishes off Oregon coast)

Poacher, blacktip (*Xeneretmus latifrons*)
J 25(12): 2665 (associations with other fishes off Oregon coast)

Poacher, bluespotted (*Xeneretmus triacanthus*)
J 25(12): 2665 (associations with other fishes off Oregon coast)

Poacher, northern spearnose (*Agonopsis emmelane*)
J 25(8): 1651 (plasma protein-bound inorganic iodide)
(12): 2665 (associations with other fishes off Oregon coast)
T 30 (in B.C. experimental trawling)

Poacher, warty (*Occa verrucosa*)
J 25(12): 2665 (associations with other fishes off Oregon coast)

Poachers (general)
T 22, 46, 62, 81 (in B.C. experimental groundfish trawling)

Podium
J 25(3): 541 (aquiferous system for expansion, in *Polinices*)

Polides rotundus (a red seaweed)
S 1239 (sterols)

Polinices lewisi (*see* Clam drill)

Pollachius virens (*see* Pollock (Atlantic))

Pollock (Atlantic) (*Pollachius virens*)
CJG 14 (Nfld. landings, 1966)
15 (Nfld. landings, 1952–67)
T 80 (stocks, Gulf of St. Lawrence & N.S. Banks)
A 108 (1966 Canadian ICNAF studies: commerical catches)

Pollock, Alaska (*see* Pollock, walleye)

Pollock, Pacific (*see* Pollock, walleye)

Pollock, walleye (*Theragra chalcogrammus*) (Alaska pollock; Bigeye; Pacific pollock; Walleye; Whiting)
CHN 32 (used for Japanese fish paste)
T 7, 11, 16, 22, 30, 46, 56, 62, 81 (in experimental or commercial B.C. trawling)
34 (distribution, stocks, populations, synonymy, systematics)
A 90, 103 (Japan & USSR Bering sea fishery)
91 (1951–66 B.C. landings for mink feed)

Pollution (*see also* Insecticides: Pesticides)
J 25(3): 591; (11): 2461; (12): 2691 (effects of radioactive ^{65}Zn from atomic reactors on trout and invertebrates)
(7): 1369 (pulpmill, re walleye fishery in Nipigon Bay region, Ont.)
R 1965–1966: 47, 108 (summary of Board investigations)
CVG 38 (clarifying salmon-canning wastewater to minimize)
T 14 (clarifying waste-water from B.C. fish plants)
S 1196 (Cu & Zn mining effluent effect on Atl. salmon)
1252 (rainbow trout avoidance reactions to Zn sulphate)
A 81 (chart of types & chemical analyses for; effects on waters)
83 (criteria for pesticide (DDT) residues re effects on fish)
84 (impact on Atl. Provinces fisheries)
87 (detection & measurement by biological assays)
111 (NTA sequestering agent to combat metal ions)

Polychaeta
T 25, 35, 59, 60, 73 (in Strait of Georgia benthos biomass)
43 (on Irish moss)
55 (identification of B.C.)
76 (in tidal Ostrea L., N.S.)
S 1219 (Errantia: checklist of B.C. since 1923)
1243 (Sedentaria: checklist of B.C. since 1923)

Polypeptides (*see* Protein)

Polyphosphates (*see* Phosphates)

Pomoxis nigromaculatus (*see* Crappie, black)

Ponding (*see* also Pound)
J 25(2): 209 (effect on brook trout catches)

Populations (*see also* Stocks)
J 25(1): 101 (sympatric & allopatric, of suckers, re hybridization)
(2): 255 (of small fishes: estimation by staining)
(3): 555 (analysis of S Gulf of St. Lawrence cod)
(7): 1349, 1365 (of walleye in Nipigon Bay area, Ont.)
(9): 1813 (F) (two sympatric, of American smelt)
(11): 2349 (echo sounding for direct estimation of hake)
S 1204 (units of scombrids re serum transferrin polymorphism)
1230 (of Canadian N Pac. spawning salmons)

Porbeagle (*Lamna nasus*)
A 108 (1966 Canadian ICNAF studies: catch)

Porichthys notatus (*see* Midshipman, northern)

Porifera
T 73 (in strait of Georgia benthos biomass)

Poromitra rugosus (*see* Melamphid, crested)

Porphyra (red seaweeds)
S 1239 (sterols)

Porpoise, Gulf of California harbour (*Phocoena sinus*)
J 25(12): 2561 (feeding habits from fish otoliths in stomach)

Porrocaecum decipiens (*see* Codworm)

Port John Lake, B.C.
B 162 : 184 (re B.C. sockeye salmon studies)

Potassium compounds
A 85 (in freshwater fishmeals)

Poultry (*see* Chicken)

Pound (*see also* Ponding)
T 78 (octagonal, for live fish)

Powell, Neil Andrew
J 25(11): 2269 (Canadian arctic Bryozoa)

Power, Geoffrey
J 25(4): 657 (Ungava round whitefish age & growth)
(10): 2225 (Bay of Quinte white perch)
(10): 2071 (haddock preserved by ethylenediaminetetraacetic acid)

Power, Henry Edwin
T 67 (volumetric determination of EDTA)
68 (colorimetric determination of EDTA salts on haddock, cod, & flounder)
69 (Atl. coast mechanical unloading devices)

Powers, Charles Fales
J 25(6): 1181 (upper Great Lakes benthic environment)

Powles, Percival Mount
J 25(3): 597 (yellowtail flounder *Ichthyophonus* infection)
S 1212 (greysole age determination by otoliths)
1213 (ICNAF Subarea 4 plaice, witch & yellowtail flounder)

Prasinophyceae
J 25(8): 1603 (fatty acids re taxonomy)

Prawn (*Pandalus platyceros* (spot shrimp)) (*see also* Shrimp)
CNG 85 (1967 prospecting for, in B.C.)
T 22, 30, 81 (in B.C. experimental groundfish trawling)
A 104 (based on CNG 85 above)

Predation (*see also* Feed)
J 25(10): 2011 (control to increase trout yield in lake)
B 162 : 83, 239 (by & on sockeye salmon)
165 : 66 (on & by carp)
T 42 (clam drill on Pac. clams)

Preservatives and preservative treatments (*see also* Antibiotics; Antioxidants; Freezing; Irradiation; Rancidity; Refrigeration)
J 25(8): 1753; (10): 2071 (EDTA & CTC as bactericides & bacteriostats)
(12): 2623 (cryogenic, of Atl. cod sperm)
CSG 52 (antifouling coatings for vessels)
T 67, 68 (chemical analysis for EDTA residues in fish products)
A 77, 78 (brief summaries of several types)
88 (same as CSG 52 above)

Pressure
J 25(7): 1311 (effect on respiration of vertically migrating Crustacea)

Prest, Janice
T 56 (1967 B.C. trawl fishery catch & effort statistics)
89 (B.C. trawl fishery, 1967)

Priapulida
T 60 (in Strait of Georgia benthos biomass)

Prickleback (*see Anoplarchus insignis*)

Prickleback, black-and-white (*Plectobranchus evides*)
J 25(12): 2665 (associations with other fishes off Oregon coast)

Prince Edward Island (*see also* Ellerslie Brook)
J 25(11): 2521 (oyster gill worm in oysters)
B 166 : 47 (eel fishery)

Prionace glauca (*see* Shark, blue)

Pristanic acid (*see* Acids, fatty)

Processing of fishery products (*see* methods of processing; *also* types of commercial fishery products)

Prodrome
T 2 (for distributional checklist & bibliography of recent Canada W coast marine Mollusca)

Production (*see* Catches: Fisheries; *also* names of commercial organisms)

Productivity, primary (*see also* Carbon content; Matter, particulate)
J 25(4): 625 (production & mineralization in a Japan inlet)
(10): 2037 (& algal growth in a thermal stream)
(10): 2101 (nitrogen fixation in subarctic lake)
B 162 : 209 (re sockeye salmon feed)
167 (analytical methods for determination in sea water)
T 77 (St. Margaret's Bay, N.S. 1967)
A 108 (1966 Canadian ICNAF studies on Atl. Ocean)
115 (new Board laboratory at Dartmouth, N.S., for study of marine)

Prolactin
J 25(7): 1497 (ovine vs. chinook salmon pituitary extract effect on hypophysectomized goldfish)

Prosopium cylindraceum (*see* Whitefish, round)

Prospecting (*see* Exploration)

Protamine
S 1245 (biosynthesis during salmonid spermatogenesis)

Protein (*see also* Acids, amino; Browning; Muscle; Proteolysis)
J 25(7): 1317 (muscle: inheritance in hybrids)
(8): 1651 (inorganic iodide binding in plasma)
(10): 2059 (extractability re free fatty acids in iced cod muscle)
(11): 2477 (electrophoresis of muscle, from 30 rockfish species re systematics)
S 1195 (malonaldehyde reaction with myosin re rainbow trout muscle denaturation)
1232 (polypeptide chains re denaturants)
A 79 (denaturation re freezing & cold storage)

Protein concentrate ("fish flour")
J 25(4): 805 (isopropyl alcohol extraction solvent retention by)
A 98 (composition of Atl. herring & cod)

Proteolysis
J 25(5): 921 (re nonbacterial trimethylamine formation in frozen Atl. cod & scallop muscle)
A 78 (brief summary re bacterial spoilage)

Protothaca staminea (*see* Clam, little-neck)

Protozoa (*see* Zooplankton)

Prowfish (*Zaprora silenus*)
T 11 (in B.C. experimental midwater trawling)

Psammobatis spinosissimus (an Oregon coast skate)
J 25(12): 2665 (associations with other Oregon coast fishes)

Psettichthys melanostictus (*see* Sole, sand)

Pseudomonas (bacteria)
S 1258 (proteinase in species causing trout skin lesions)

Pseudopleuronectes americanus (*see* Flounder, winter)

Psychrolutes paradoxus (*see* Sculpin, tadpole)

Ptarmigan, rock (*Lagopus mutus*)
S 1201 (occurrence off N Labrador)

Pterophyllum eimekei (*see* Angelfish)

Pteropoda
J 25(2): 267 (*Limacina helicina* retention of thetin derivative from feed)
CNG 84 (popular description of NE Pac. *Limacina* & *Clione*)
T 55 : 137 (identification of B.C.)

Ptychocheilus oregonense (*see* Squawfish, northern)

Publications and reports, Fisheries Research Board of Canada (*see also* Bibliographies)
J 25(12) (list of 1968 and some 1967)
B 164 (list of titles, & those of certain relevant publications, 1900–1964, with subject–author index)
R 1965–1966: 111 (list of 1965 & 1966)

Pulmonata
T 2 (distributional checklist & bibliography of B.C. marine)

Pulp mill effluents (*see* Pollution)

Pumpkinseed (*Lepomis gibbosus*) (pumpkinseed sunfish)
J 25(6): 1133 (diel feeding habits)
(6): 1199 (low temperature effects on feeding in 3 Ont. streams)

Pumps
T 69 (for unloading fish from fishing vessels)

Pungitius pungitius (*see* Stickleback, ninespine)

Purines (*see also* Acids, nucleic; Nucleosides)
J 25(2): 239 (adenine nucleotide degradation products as quality criteria for chilled mackerel muscle)
(4): 817 (rapid accumulation of hypoxanthine in iced redfish fillets)
(9): 1901 (guanine & hypoxanthine formation in Atl. salmon)
(9): 2001 (F) (guanine in walleye & sauger retina re habitat)
(11): 2403 (re belly skin guanine in parr & smolt coho salmon)
S 1198 (re *Hemiselmis virescens* phototrophic growth)
1231 (re uricolytic enzymes in Atl. cod sperm)

Pyrrophyta
S 1197 (aldolase activity re phylogeny)

Pyruvate
S 1236, 1237 (metabolism by Atl. salmon & cod sperm)

Q

Qadri, Sami Ullah
J 25(10): 2091 (lake whitefish in Lac la Ronge)

Quahaug [quahog], bay (*Venus mercenaria*)
J 25(2): 267 (occurrence & retention of thetin derivative from feed)

Quahaug [quahog], ocean (*Arctica islandica*)
J 25(2): 267 (occurrence & retention of thetin derivative from feed)

Quality of fishery products (*see also* Grading; Odours; Preservatives; *also* types of processing and products)
J 25(2): 239 (adenine nucleotide degradation products as criteria of, in chilled mackerel muscle)
(2): 299 (rigor & freezing–thawing effects on refrozen Atl. cod)
(3): 605 (ultrasonic backscatter as test, for frozen & thawed flesh)
(4): 733 (of frozen trap-caught Atl. cod re prior handling)
(4): 817 (unreliability of hypoxanthine test for)
(4): 829 (re seasonal changes in thaw-drip in American plaice fillets)
(5): 921 (nonbacterial trimethylamine formation in frozen Atl. cod & scallop muscle)
(5): 935 (of gillnetted Atl. cod skeletal muscle)
(8): 1753 (of flesh treated with EDTA & CTC)
(10): 2071 (of haddock fillets treated with EDTA)
(11): 2453 (dimethyl sulphide a natural constituent of odour of fresh soft-shell clams)
R 1965–1966: 25, 76 (summary of Board investigations)
T 69 (of fish unloaded from vessels by mechanical means)

A 78, 79, 80 (re bacterial action; freezing effects; nutritive value)

Quebec (*see also* St. Lawrence, Gulf of)
B 166 : 50 (eel fishery)

Queen Charlotte Islands region, B.C. (*see also* Oceanography, B.C. coast; Oceanography, North Pacific Ocean)
T 11 (experimental midwater trawl catches, 1964–65)
30, 46, 62 (experimental groundfish catches)

Queen Elizabeth Islands, Canadian Arctic
J 25(2): 347 (hippolytid & crangonid shrimps)

Quimby, Millicent Childs
J 25(2): 383 (infectious pancreatic necrosis virus-free trout selection)

Quinte, Bay of (Lake Ontario)
J 25(10): 2225 (white perch reproduction)

R

Rabbit
J 25(12): 2711 (muscle creatine kinase localization)

Radiation (*see also* Irradiation; Isotopes; Light, reactions to)
J 25(10): 2219 (loss of ^{14}C-labelled radioactivity from stored phytoplankton)
(11): 2505 (measuring self-absorption of ^{14}C)
S 1259 (sockeye salmon sexual maturity effects on clearing of injected radioactive cortisol)

Radulinus asprellus (*see* Sculpin, slim)

Rafail, Samir Zaky
J 25(4): 717 (plaice ration & growth)

Raja binoculata (*see* Skate, big)

Raja clavata
S 1244 (a corticosteroid 1α-hydroxylase in interrenal tissue)

Raja erinacea (*see* Skate, little)

Raja kincaidi(i) (*see* Skate, black)

Raja laevis (*see* Skate, barndoor)

Raja ocellata (*see* Skate, winter)

Raja radiata (*see* Skate, thorny)

Raja rhina (*see* Skate, longnose)

Raja stellulata (*see* Skate, starry)

Raja trachura (*see* Skate, roughtail)

Rake
T 15 (digging efficiency of fork vs. hydraulic rake for B.C. clams)

Rana pipiens (*see* Frog)

Rancidity, oxidative (*see also* Antioxidants)
J 25(4): 639 (acceleration by metal ions, in marine flesh)

Range extensions (*see* Species, new records)

Rao, Desiraju Bhavanarayana
J 25(6): 1097 (Bay of Fundy natural oscillations)

Rat, white (*Rattus norvegicus*)
J 25(8): 1651 (plasma protein-bound inorganic iodide)
S 1203 (positional distribution of monoenoic fatty acids in triglycerides)
1233 (marine fatty acids incorporation into fat of tissues)

Ratfish (*Hydrolagus colliei*)
J 25(2): 339 (host to new parasitic Chondracanthid copepod)
(8): 1651 (plasma protein-bound inorganic iodide)
(12): 2665 (associations with other Oregon coast fishes)
T 7, 11, 22, 30, 46, 56, 62, 81 (in B.C. experimental or commercial trawling)
A 91 (observed in B.C. catches of fish for mink feed)

Ration (*see* Feed)

Rattail, filamented (*Coryphaenoides filifera*)
T 81 (in B.C. experimental groundfish trawling)

Rattail, pointed (*Coryphaenoides pectoralis*)
J 25(12): 2665 (associations with other Oregon coast fishes)

Rattail, roughscale (*Coryphaenoides acrolepis*)
J 25(12): 2665 (associations with other Oregon coast fishes)
T 22 (in B.C. experimental midwater trawling)

Rattus norvegicus (*see* Rat, white)

Ravesi, Elinor Mae
J 25(10): 2059 (protein extractability & free fatty acid in cod)

Records, new (*see* Species, new; Species, new records)

Recruitment (*see also* Stocks)
J 25(12): 2701 (simplified computation of rates)

"Red tide"; "red water"
J 25(8): 1749 (bloom in Gulf of Maine caused by red ciliate)

Redfish (*Sebastes marinus* (*mentella*))
J 25(4): 639 (catalysis of flesh oxidative rancidity by metal ions)
(4): 817 (rapid hypoxanthine accumulation in iced fillets)
(5): 906 (as redfish feed in NW Atl.)
(5): 1061 (fatty acids of commercial liver oil)
(11): 2477 (proteins electropherograms re rockfishes systematics)
CJG 14 (Nfld. landings, 1966)
15 (Nfld. landings, 1952–67)
T 80 (stocks, Gulf of St. Lawrence & N.S. Banks)
A 99 (fishery yields, 1952–64)
108 (1966 Canadian ICNAF studies: commercial catches; temperature effects)

Reduction (*see also* Fishmeals; Oils and fats)
T 7, 19, 56, 89 (B.C. landings of fish for)

Reef
J 25(12): 2683 (artificial, for lobsters)

Refrigeration (*see also* Chilling; Freezing)
J 25(2): 299 (storage quality of Atl. cod after thawing)
(2): 363; (6): 1295 (of Atl. salmon sperm)
(5): 921 (nonbacterial trimethylamine production in frozen Atl. cod & scallop muscle)

Regulation (*see* Fisheries; Management; *also* names of International Commissions)

Rehabilitation (*see also* Conservation; Hatchery)
J 25(7): 1377 (of lake trout in Apostle Is. region, L. Superior)

Reimers, Paul Edward
J 25(9): 2005 (chinook salmon social behavior)

Reisman, Howard Maurice
J 25(12): 2703 (blackspotted stickleback reproductive isolating mechanisms)

Reproduction (*see also* Eggs; Fecundity; Spawning; Sperm; *also* names of organisms)
J 25(9): 1787 (of brook trout as affected by DDT insecticide)
(10): 2091 (of lake whitefish in Lac la Ronge, Sask.)
(10): 2225 (white perch, Bay of Quinte, L. Ontario)
(12): 2703 (isolating mechanisms of blackspotted stickleback)
B 162 (sockeye salmon)

Respiration (*see also* Activity; Blood; Gills; Oxygen, dissolved)
J 25(7): 1311 (pressure effect on vertically migrating crustacean)
(8): 1689 (goldfish & rainbow trout respiratory quotient)
(8): 1729 (O_2 consumption of crab & lobster at low temperature)
(12): 2603 (goldeye)
MSP 10 : 14 (respirometer for fish swimming speed re water temperature)
A 116 (fish respirometer)

Retina (*see* Eye)

Reviews (*see* also Bibliography)
B 162 (sockeye salmon)
165 (carp in Canada)
166 (eel fisheries of E Canada)
AR 1967 (Fisheries Research Board of Canada Annual Report)
R 1965–1966 (Fisheries Research Board of Canada biennial Review)

Rhacochilus vacca (*see* Perch, pile)

Rheotaxis
J 25(8): 1591 (selectivity for different stream waters by American eel)

Rhinichthys atratulus (*see* Dace, blacknose)

Rhinichthys cataractae (*see* Dace, longnose)

Rhinoliparis attenuatus (an Oregon coast fish)
J 25(12): 2665 (associations with other fishes off Oregon coast)

Rhizoprionodon species (*see* Shark, sharpnose)

Rhodomela confervoides (a red seaweed)
S 1239 (sterols)

Rhodophyceae
J 25(8): 1603 (fatty acids)
S 1239 (sterols)

Rhodymenia palmata (*see* Dulse)

Riboflavin (*see* Vitamin B group)

Richard, Joseph Donat
J 25(7): 1441 (fish attraction with pulsed low-frequency sound)

Richardsonius balteatus (*see* Shiner, redside)

Ricker, William Edwin
J 25(7): 1423 (N American species of *Taeniopteryx*)
(12): 2743 (mean weight from length statistics)
A 106 (Pac. salmon move east)

Abbreviations: J — Journal; B — Bulletin; AR — Annual Report; R — Review; *Circular series*: CDG — Dartmouth; CHN — Halifax; CJG — St. John's; CNG, CNS — Nanaimo; CSG — St. Andrews; CVG — Vancouver; T — Technical Reports; MSP — Miscellaneous Special Publications; S — Studies; A — Interpretive Articles.

Rigor
J 25(2): 299; (4): 733 (effect on refrozen Atl. cod storage quality)

Rivers Inlet, B.C. (*see also* Salmon)
S 1230 (spawning populations of sockeye & other salmons)

Rivulus, striped (*Rivulus strigatus*)
J 25(8): 1739 (spinal ganglia position re taxonomy)

Roach (*Rutilus rutilus*)
J 25(12): 2711 (muscle creatine kinase localization)

Roberts, Eve
J 25(11): 2477 (protein electrophoresis re rockfish systematics)

Robertson, Andrew
J 25(6): 1181 (upper Great Lakes benthic environment)

Roccus americanus (*see* Perch, white)

Roccus chrysops (*see* Bass, white)

Rockfish, aurora (*Sebastodes aurora*)
J 25(11): 2477 (proteins electropherograms re rockfishes systematics)
(11): 2509 (first B.C. record)
T 22, 81 (in B.C. experimental groundfish trawling)

Rockfish, black (*Sebastodes melanops*)
J 25(11): 2477 (proteins electropherograms re rockfishes systematics)
(12): 2665 (associations with other fishes off Oregon coast)
T 7, 11, 56 (in B.C. experimental or commercial trawling)

Rockfish, blackblotched (*see* Rockfish, blackmouth)

Rockfish, blackgill (*Sebastodes melanostomus*)
T 56 (in B.C. commercial trawling)

Rockfish, blackmouth (*Sebastodes crameri*) (blackblotched rockfish)
J 25(11): 2477 (proteins electropherograms re rockfishes systematics)
(12): 2665 (associations with other fishes off Oregon coast)
T 11, 22, 30 46, 56, 62, 81 (in experimental or commercial B.C. trawling)

Rockfish, blackthroat (*Sebastodes aleutianus*) (rougheye rockfish)
J 25(11): 2477 (proteins electropherograms re rockfishes systematics)
T 11, 22, 30, 46, 56, 62, 81 (in B.C. experimental or commercial trawling)

Rockfish, blue (*Sebastodes mystinus*)
J 25(11): 2477 (proteins electropherograms re rockfishes systematics)
T 30 (in B.C. experimental groundfish trawling)

Rockfish, canary (*Sebastodes pinniger*) (orange rockfish)
J 25(4): 801 (early larvae pigment patterns)
(11): 2477 (proteins electropherograms re rockfishes systematics)
T 7, 11, 22, 30, 46, 56, 62, 81 (in experimental or commercial B.C. trawling)
A 91 (observed in B.C. landings of fish for mink feed)

Rockfish, China (*Sebastodes nebulosus*) (yellowstripe rockfish)
J 25(11): 2477 (proteins electropherograms re rockfishes systematics)
T 56 (in B.C. commercial groundfish trawling)

Rockfish, copper (*Sebastodes caurinus*)
J 25(8): 1651 (plasma protein-bound inorganic iodide)
(11): 2477 (proteins electropherograms re rockfishes systematics)
T 7, 56 (in B.C. commercial groundfish trawling)

Rockfish, cow (*Sebastodes levis*)
T 30 (in B.C. experimental groundfish trawling)

Rockfish, dusky (*Sebastodes ciliatus*)
J 25(11): 2477 (proteins electropherograms re rockfishes systematics)
(11): 2509 (first B.C. record)
T 11, 46 (in experimental B.C. trawling)

Rockfish, flag (*Sebastodes rubrivinctus*)
J 25(11): 2477 (proteins electropherograms re rockfishes systematics)
T 7, 22, 30, 46, 56, 62, 81 (in B.C. experimental or commercial trawling)

Rockfish, greenstriped (*Sebastodes elongatus*)
J 25(11): 2477 (proteins electropherograms re rockfishes systematics)
(12): 2665 (associations with other fishes off Oregon coast)
T 7, 11, 22, 30, 46, 56, 62, 81 (in experimental or commercial B.C. trawling)

Rockfish, longjaw (*see* Perch, Pacific ocean)

Rockfish, longspine channel (*Sebastolobus altivelis*)
J 25(11): 2477 (proteins electropherograms re rockfishes systematics)
(11): 2509 (first B.C. record)
(12): 2665 (associations with other fishes off Oregon coast)
T 22, 81 (in B.C. experimental groundfish trawling)

Rockfish, northern (*Sebastodes polyspinis*)
J 25(11): 2477 (proteins electropherograms re rockfishes systematics)

Rockfish, pigmy (*Sebastodes wilsoni*)
J 25(11): 2477 (proteins electropherograms re rockfishes systematics)
(12): 2665 (associations with other fishes off Oregon coast)
T 22, 81 (in B.C. experimental groundfish trawling)

Rockfish, quillback (*Sebastodes maliger*)
J 25(8): 1539 (postmortem starch degradation)
(8): 1651 (plasma protein-boundin organic iodide)
(11): 2477 (proteins electropherograms re rockfishes systematics)
T 7, 56, 62 (in B.C. experimental or commercial trawling)

Rockfish, rasphead (*see* Snapper, red)

Rockfish, redstripe (*Sebastodes proriger*)
J 25(11): 2477 (proteins electropherograms re rockfishes systematics)
(12): 2665 (associations with other fishes off Oregon coast)
T 7, 11, 16, 22, 30, 46, 56, 81 (in B.C. experimental or commercial trawling)

Rockfish, rosethorn (*Sebastodes helvomaculatus*)
J 25(11): 2477 (proteins electropherograms re rockfishes systematics)
(12): 2665 (associations with other fishes off Oregon coast)
T 11, 22, 30, 46, 56, 81 (in B.C. experimental or commercial trawling)

Rockfish, rougheye (*see* Rockfish, blackthroat)

Rockfish, sharpchin (*Sebastodes zacentrus*)
J 25(11): 2477 (proteins electropherograms re rockfishes systematics)
(12): 2665 (associations with other fishes off Oregon coast)
T 11, 16, 22, 46, 56, 81 (in experimental or commercial B.C. trawling)

Rockfish, shortbelly (*Sebastodes jordani*)
J 25(11): 2477 (proteins electropherograms re rockfishes systematics)
T 22 (in B.C. experimental groundfish trawling)

Rockfish, silvergray (*Sebastodes brevispinis*)
J 25(11): 2477 (proteins electropherograms re rockfishes systematics)
T 7, 11, 22, 30, 46, 56, 62, 81 (in experimental or commercial B.C. trawling)

Rockfish, spinycheek (*Sebastolobus alascanus*)
J 25(8): 1539 (postmortem muscle glycogen & starch degradation)
(11): 2477 (proteins electropherograms re rockfishes systematics)
(12): 2665 (associations with other fishes off Oregon coast)
T 7, 22, 46, 56, 81 (in B.C. experimental or commercial trawling)
34 (distribution, stocks, populations, synonymy, systematics)

Rockfish, splitnose (*Sebastodes diploproa*)
J 25(11): 2477 (proteins electropherograms re rockfishes systematics)
(12): 2665 (associations with other fishes off Oregon coast)
T 7, 16, 22, 30, 46, 56, 81 (in B.C. experimental or commercial trawling)

Rockfish, stripetail (*Sebastodes saxicola*)
J 25(11): 2477 (proteins electropherograms re rockfishes systematics)
(12): 2665 (associations with other fishes off Oregon coast)
T 22, 30, 46, 81 (in B.C. experimental trawling)

Rockfish, tiger (*Sebastodes nigrocinctus*)
J 25(8): 1651 (plasma protein-bound inorganic iodide)
T 56 (in B.C. commercial trawling)

Rockfish, vermilion (*Sebastodes miniatus*)
T 56 (in B.C. commercial trawling)

Rockfish, widow (*Sebastodes entomelas*)
J 25(11): 2477 (proteins electropherograms re rockfishes systematics)
(12): 2665 (associations with other fishes off Oregon coast)
T 11, 16, 22, 46, 56, 81 (in experimental or commercial B.C. trawling)

Rockfish, yellowmouth (*Sebastodes reedi*)
J 25(11): 2477 (proteins electropherograms re rockfishes systematics)
T 46, 56, 62, 81 (in B.C. experimental or commercial trawling)

Rockfish, yellowstripe (*see* Rockfish, China)

Rockfish, yellowtail (*Sebastodes flavidus*)
J 25(11): 2477 (proteins electropherograms re rockfishes systematics)
T 7, 11, 22, 30, 46, 56, 62, 81 (in B.C. experimental or commercial trawling)

Rockfishes (Atlantic) (*see also* names of species)
J 25(11): 2477 (proteins electropherograms re systematics)

Rockfishes (Pacific) (*see also* names of species)
J 25(11): 2477 (proteins electropherograms re systematics)
A 91 (1951–66 B.C. landings for mink feed; 11 species observed)

Roe (*see* Eggs, fish)

Ronald, Keith
T 48 (checklist of parasites of lampreys)

Ronquil, northern (*Ronquilus jordani*)
J 25(12): 2665 (associations with other fishes off Oregon coast)

Ross, Herbert Holdsworth
J 25(7): 1423 (N American species of *Taeniopteryx*)

Royer, Leroy Merne
J 25(7): 1511 (Sask. R. lake sturgeon age & growth)

Ruggieri, George Daniel
J 25(3): 597 (yellowtail flounder *Ichthyophonus* infection)

Ruggles, Charles Paul
A 84 (water pollution re fisheries of Atl. provinces)

Rutilus rutilus (*see* Roach)

Ryder, Richard Armitage
J 25(7): 1347 (walleye dynamics & exploitation)

S

Sabinea septemcarinata (a crangonid shrimp)
J 25(2): 347 (Queen Elizabeth Is., Canadian Arctic)

Sable Island (N.S.)
S 1199 (ancient oyster & bay scallop shells)
1215 (sea surface temperatures, 1900–65)

Sablefish (*Anoplopoma fimbria*) (blackcod)
J 25(4): 825 (feeding behaviour in NE Pac.)
(10): 2237, 2247 (subcutaneous dart tag)
(12): 2665 (associations with other fishes off Oregon coast)
T 7, 11, 19, 22, 30, 46, 56, 62, 81, 89 (in B.C. experimental or commercial trawling)
74 (1964–65 biological & morphological study)
78 (octagonal pound for holding live)
A 91 (observed in B.C. landings of fish for mink feed)

Sagamichthys abei (?) (a searsid fish)
T 11 (in midwater trawl catch off Queen Charlotte Is.)

Sagitta elegans (a chaetognath)
CNG 84 (popular description)
A 108 : 17 (1966 Canadian ICNAF studies on parasites of)

Saint (*in addition to following headings, see* St.)

Saint-François, Lake, Que.
J 25(9): 1831 (F) (maskinonge age & growth)

Saint-Joseph, Lake, Que.
J 25(9): 1831 (F) (maskinonge age & growth)

Saint-Louis, Lake, Que.
J 25(9): 1831 (F) (maskinonge age & growth)

Saito, Akira
CHN 32 (fish paste products)
S 1239 (red algae sterols)

Salinity, reactions to (*see also* Acclimation)
J 25(3): 495 (English sole early development)
(12): 2717 (re upper lethal temperatures of acclimated mummichog & banded killifish)

Salinity of marine waters (*see also* Hydrography; Oceanography)
B 167 : 11, 17 (determination of)
T 32, 70, 82 (B.C. coast)
54 (NE Pac. Ocean, 1965 & 1966)

Salmo carpio (*see* Trout, Lake Garda)

Salmo clarki clarki (*see* Trout, cutthroat)

Salmo clarki henshawi (*see* Trout, Lahontan cutthroat)

Salmo fario (*see* Trout (a European))

Salmo gairdneri (*see* Trout, rainbow; Trout, steelhead)

Salmo ischchan (*see* Trout, Sevan)

Salmo letnica (*see* Trout, Ohrid)

Salmo salar (*see* Salmon, Atlantic)

Salmo trutta (*see* Trout, brown)

Salmon (inclusive Pacific species) (*see also* individual species; *also* Kokanee; Trout, steelhead)
B 162 : 400 (interspecies hybridization)
CVG 38 (clarification of cannery wastewater for solids & oil recovery re pollution)
T 11 (in experimental B.C. midwater trawling)
24 (enumeration & sampling data, Babine R. counting fence, 1961–66)
S 1230 (spawning populations of Canadian N Pac.)

A 86 (INPFC oceanic research results, 1966)
90, 103 (fishery trends along N America Pac. coast)

Salmon, Atlantic (*Salmo salar*)
J 25(1): 1 (competitive & feeding behaviour of hatchery vs. wild parr, in aquaria)
(1): 189 (DDT residues & metabolites in)
(2): 363; (6): 1295 (frozen preservation of sperm)
(9): 1901 (temperature & photoperiod effect on guanine & hypoxanthine formation in parr–smolt transformation)
(10): 2165 (smolt survival & adult utilization, Little Codroy R., Nfld.)
(10): 2237 (subcutaneous dart tag)
(11): 2321 (degradation of DDT in)
(11): 2387 (aggression & social hierarchy in starved young)
(11): 2439 (spawning history record from scales)
(11): 2519 (marking by high-frequency electric sparks)
(12): 2651 (hemoglobin multiplicity increase with fish length)
T 4 (analysis of 1965 smolt run, Miramichi R., N.B.)
5 (evaluating N.B. forest spraying effects on fisheries)
9 (retention of "grow-thru" tags)
29 (commercial Canadian catches, 1949–65)
38 (estuarine net counting fence for trapping)
83 (bibliography of parasites & diseases)
84 (captured & marked at Little Codroy R., Nfld. counting fence)
S 1196 (Cu & Zn mining pollution effects on spawning)
1206 (characteristics of, from Labrador Sea and off W Greenland)
1217 (revised growth rate estimates, Greenland to N.B. migratory)
1218 (tagging results, Maritime Provinces, 1964–66)
1236 (lipids biosynthesis from added substrates by sperm)
1242 (evaluation of 2 ways of attaching tags to smolts)
1257 (estuarine net counting fence for trapping)
A 83, 84 (effects of DDT forest spray residues on)
108 (1966 Canadian ICNAF studies: commercial catches; smolt tagging)
111 (combating mining effluents affecting)

Salmon, chinook (*Oncorhynchus tshawytscha*) (spring salmon) (*see also* Salmon (inclusive Pacific species))
J 25(1): 71 (fluorimetric method for blood plasma cortisol)
(3): 473 (blood lactate re stress & mortality)
(3): 611 (guanidine derivatives effect on skin pigment of young)
(4): 690 (fingerling stocking of L. Michigan)
(5): 867 (olfaction & vision role in spawning bed choice)
(7): 1453 (station permanence of juvenile)
(7): 1497 (pituitary extract effect on hypophysectomized goldfish)
(9): 1971 (accuracy of ageing from scales)
(9): 2005 (social behaviour among juvenile)
(10): 2233 (fluorescent pigment tattoo marking of fingerlings)
(11): 2467 (mortality from fungus attack)
(11): 2519 (marking by high-frequency electric sparks)
B 162 : 400 (hybridization with other salmon species)
T 11, 22, 62, 81 (in B.C. experimental groundfish trawling)
S 1245 (pituitary extract promoting protamine formation in trout spermatogenesis)
1249 (goldfish spermiation as bioassay for gonadotropin in)
A 106 (history of transplantations to L. Ontario & St. John R.)

Salmon, chum (*Oncorhynchus keta*) (*see also* Salmon (inclusive Pacific species))
J 25(3): 599 (first report of fry feeding in B.C. freshwater)
(5): 1067 (otolith age vs. scale age)
(5): 1085 (feed in NE Pac. Ocean)
B 162 : 400 (hybridization with other salmon species)
CNS 26 (age, size, & sex composition of B.C. catches, 1957–63)
A 106 (history of transplantations to James Bay tributaries)

Salmon, coho (*Oncorhynchus kisutch*) (*see also* Salmon (inclusive Pacific species))
J 25(1): 49 (dissolved O_2 & CO_2 re juvenile swimming performance)
(1): 71 (fluorimetric method for blood plasma cortisol)
(1): 101 (hematological changes on folic acid deficient diet)
(4): 690 (fingerling stocking of L. Michigan)

Abbreviations: J — Journal; B — Bulletin; AR — Annual Report; R — Review; *Circular series*: CDG — Dartmouth; CHN — Halifax; CJG — St. John's; CNG, CNS — Nanaimo; CSG — St. Andrews; CVG — Vancouver; T — Technical Reports; MSP — Miscellaneous Special Publications; S — Studies; A — Interpretive Articles.

(4): 823 (fry-counting method in small streams)
(4): 825; (5): 1085 (feeding behaviour in NE Pac. Ocean)
(6): 1247 (transaminases distribution & activity in various tissues)
(8): 1745 (muscle hydrogenate as substrate for experimental growth of *Clostridium botulinum*)
(8): 1753 (preservatives effects on flesh)
(10): 2233 (fluorescent pigment tattoo marking of fingerlings)
(10): 2237 (subcutaneous dart tag for smolts)
(11): 2403 (morphological & biochemical changes during parr–smolt transformation)
(11): 2519 (marking by high-frequency electric sparks)
B 162 (244: predator on young sockeye salmon; 400: hybridization with other salmon species)
S 1262 (gear modifications for electrofishing of underyearling)
A 106 (history of transplantations to L. Michigan, Huron, & Superior)

Salmon, masu (*see* Masu)

Salmon, Pacific (*see* Salmon (inclusive Pacific species); *also* names of individual species)

Salmon, pink (*Oncorhynchus gorbuscha*) (*see also* Salmon (inclusive Pacific species))
J 25(4): 757 (marine mortality schedules)
(5): 1085 (feed habits in NE Pac. Ocean)
(6): 1247 (transaminases distribution & activity in various tissues)
(9): 1993 (another 3rd-year)
(12): 2695 (chilled storage effect on ova & sperm)
B 162 : 400 (hybridization with other salmon species)
CJG 14 : 32; 15: 24 (increasing establishment in Nfld. from egg transplants from B.C.)
T 17 (micromagnetic tags for fry)
A 106 (history of egg transplantations to Hudson Bay tributaries, L. Superior, & Nfld. river)
108 (1966 Canadian ICNAF studies: egg transplantations from Pac. coast; predation & return on Atl. coast)
113 (review of egg transplants to Nfld.)

Salmon, redspot (*Oncorhynchus rhodurus*)
A 106 (suitability for possible transplantation into the Great Lakes)

Salmon, sockeye (*Oncorhynchus nerka*) (*see also* Kokanee; Salmon (inclusive Pacific species))
J 25(1): 71 (fluorimetric method for blood plasma cortisol)
(3): 473 (blood lactate re stress & mortality)
(3): 485 (behaviour & distribution when spawning on Alaskan lake beaches)
(5): 1067 (otolith age vs. scale age)
(5): 1085 (feed habits in NE Pac. Ocean)
(6): 1115 (sounding response)
(6): 1219 (ocean mortality estimation for Bristol Bay sockeye salmon)
(6): 1247 (transaminases distribution & activity in various tissues, & in kidney diseased)
(7): 1465 (metopirone effect on pituitary–interrenal function)
(10): 2237 (subcutaneous dart tag)
(12): 2695 (chilled storage effect on ova & sperm)
B 162 (422 pages on all aspects of biology, etc., particularly in B.C.)
T 10 (age, size, & sex composition of Lakelse L., B.C., 1965 & 1966 spawning run)
S 1245 (pituitary extract promoting protamine in steelhead trout spermatogenesis)
1250 (sexual maturation effects on injected radioactive cortisol)
A 116 (fish respirometer for metabolism studies)

Salmon, spring (*see* Salmon, chinook)

Salmon, steelhead (*see* Trout, rainbow; Trout, steelhead)

Salmon-lice
S 1206 (*Lepeophtheirus salmonis* on Atl. salmon)

Salmonidae (*see also* individual species)
J 25(1): 71 (fluorimetric method for blood plasma cortisol)
(10): 2233 (fluorescent pigment tattoo marking of fingerlings)

Salvelinus malma (*see* Dolly Varden)

Salvelinus namaycush (*see* Trout, lake)

Sampling; Sampling devices (*see also* Apparatus)
J 25(6): 1169 (tidewater Atl. herring larvae with nets)
(8): 1741 (for plankton from frozen lakes)
B 162 : 164, 219, 220 (tow & plankton nets)

Sand lance, northern (*Ammodytes dubius*)
J 25(9): 1775 (morphometrics, distribution, growth, & maturity; off N.S. banks)

Sand lance, Pacific (*Ammodytes hexapterus*)
T 11, 46, 62, 89 (in B.C. experimental or commercial trawling)

Sanddab, mottled (*see* Sanddab, Pacific)

Sanddab, Pacific (*Citharichthys sordidus*) (mottled sanddab)

J 25(12): 2665 (associations with other fishes off Oregon coast)
T 7, 11, 22, 56, 62, 81 (in B.C. experimental & commercial trawling)
A 91 (observed in B.C. landings of fish for mink feed)

Sanddab, speckled (*Citharichthys stigmaeus*)
J 25(12): 2665 (associations with other fishes off Oregon coast)
T 7, 56 (in B.C. experimental & commercial trawling)
A 91 (observed in B.C. landings of fish for mink feed)

Saprolegnia parasitica (*see* Fungus)

Sarcoplasm
J 25(8): 1581 (malic enzymes in fish muscle)

Sarda chiliensis (*see* Bonito, Pacific)

Sardine, California (*Sardinops caerulea*) (pilchard)
A 90, 103 (theories of decline of fishery)

Sardinops caerulea (*see* Sardine, California)

Saskatchewan River
J 25(7): 1511 (age & growth of lake sturgeon in delta)

Satellite Channel, B.C.
T 25, 35, 59 (quantitative benthic investigations, 1965–67)

Sauger (*Stizostedion canadense*)
J 25(9): 2001 (F) (retinal structure re habitat turbidity)

Saunders, John Wilfred
J 25(2): 209 (pond formation re brook trout catches)

Saunders, Richard Lee
S 1196 (copper–zinc mining pollution on spawning salmon)
1242 (tagging salmon smolts)

Saury, Pacific (*Cololabis saira*)
J 25(4): 825 (as feed in NE Pac.)
CHN 32 (used in Japanese fish paste)

Savagaon, Kadayya Annayya
J 25(10): 2071 (haddock preserved by ethylenediaminetetraacetic acid)

Saxidomus giganteus (*see* Clam, butter)

Scales, fish
J 25(5): 1067 (vs. otoliths for chum & sockeye salmon ageing)
(7): 1333 (incorporation of Sr from Sr-rich diet for marking goldfish)
(9): 1831 (F) (maskinonge)
(9): 1901 (guanine & hypoxanthine formation in Atl. scales)
(9): 1971 (re accuracy of ageing chinook salmon)
(9): 1993 (of a 3rd-year pink salmon)
(10): 2111 (annulus formation in 4 coregonid species)
(11): 2439 (as Atl. salmon spawning history record)
(11): 2519 (marking fish by high-frequency electric spark modification of scales)
B 162 : 9, 381 (re sockeye salmon age & stocks identification)
T 49 (for Atl. herring ageing)
74 (vs. otoliths for sable fish ageing)
MSP 10 : 12 (age determination from)

Scallop, bay (*Aequipecten irradians sablensis*)
S 1199 (ancient shells on Sable Is., N.S.)

Scallop, giant (*Placopecten magellanicus*) (sea scallop)
J 25(2): 267 (occurrence & retention of thetin derivative from feed)
(4): 639 (catalysis of muscle oxidative rancidity by metal ions)
(5): 921 (nonbacterial trimethylamine production in frozen muscle)
(7): 1339 (striated muscle ultrastructure)
(10): 2123 (underwater observations of behaviour & drag efficiency)
S 1226 (fatty acids positional distribution in hepatopancreas triglycerides)
A 108 (1966 Canadian ICNAF studies: exploration; commercial catches)

Scallop, Iceland (*Chlamys islandicus*)
A 108 (1966 Canadian ICNAF studies: exploration for)

Scallop, sea (*see* Scallop, giant)

Scaphopoda
T 2 (distributional checklist & bibliography of B.C. marine)
25, 35, 59, 60, 73 (in Strait of Georgia benthos biomass)

Scarratt, David Johnson
J 25(2): 427 (lobster larvae off N.S.)
(12): 2683 (artificial reef for lobsters)

Scatophagus argus (*see* Butterfish, spotted)

Schmidt, Peter Joseph
J 25(1): 71 (cortisol in salmonid plasma)

Schoettger, Richard Aaron
J 25(1): 25 (rainbow trout M.S. 222 excretion)

Schooling
J 25(2): 393 (effect of light on jack mackerel)
(4): 711 (seasonal effect on yellow perch)

Sclerocrangon ferox (a crangonid shrimp)
J 25(2): 347 (Queen Elizabeth Is., Canadian Arctic)

Scomber japonicus (*see* Mackerel, Pacific)

Scomber scombrus (*see* Mackerel, Atlantic)

Scomberomorus sierra (*see* Mackerel, Sierra)

Scopelosaurus harryi (a scopelosaurid fish)
T 11 (in experimental B.C. midwater trawl)

Scopes, Robert Kerry
J 25(12): 2711 (fish creatine kinase in electrophoretic patterns)
(12): 2715 (carp muscle creatine kinase)

Scorpaena guttata (*see* Scorpionfish, California)

Scorpaenichthys marmoratus (*see* Cabezon)

Scorpaenidae (*see* Rockfishes; *also* names of individual species)

Scorpaenodes xyris (a rockfish)
J 25(11): 2477 (muscle protein electropherograms re rockfishes systematics)

Scorpionfish, California (*Scorpaena guttata*)
J 25(11): 2477 (proteins electropherograms re rockfishes systematics)

Scott, James Stuart
J 25(9): 1775 (offshore sand launce)

Scott, William Beverley
J 25(5): 903 (swordfish feeding habits)
(5): 1075 (*Dasyatis violacea* in NW Atl.)

Sculpin, arctic staghorn (*Gymnocanthus tricuspis*)
J 25(12): 2729 (in Nfld. waters)

Sculpin, blackfin (*Malacottus kincaidi*)
T 11 (in B.C. experimental midwater trawling)

Sculpin, buffalo (*Enophrys bison*)
J 25(4): 807 (feed of)
(8): 1651 (plasma protein-bound inorganic iodide)

Sculpin, deepwater (*Myoxocephalus thompsonii*)
J 25(4): 667 (re Great Lakes species succession & exploitation)
(12): 2733 (first record from Ottawa Valley, Que.)

Sculpin, filamented (*see* Sculpin, threadfin)

Sculpin, great (*Myoxocephalus polyacanthocephalus*)
J 25(2): 323 (host to parasitic Chondracanthid copepod)

Sculpin, lesser filamented (*see* Sculpin, spotfin)

Sculpin, Pacific staghorn (*Leptocottus armatus*)
J 25(8): 1651 (plasma protein-bound inorganic iodide)
T 7, 56 (in B.C. commercial trawling)
A 91 (observed in B.C. landings of fish for mink feed)

Sculpin, prickly (*Cottus asper*)
J 25(9): 1997 (diel limnetic occurrence of young)
B 162 : 245 (predation on young sockeye salmon)

Sculpin, roughback (*Chitonotus pugetensis*)
J 25(12): 2665 (associations with other fishes off Oregon coast)

Sculpin, slim (*Radulinus asprellus*) (darter sculpin)
J 25(12): 2665 (associations with other fishes off Oregon coast)

Sculpin, spoonhead (*Cottus ricei*)
J 25(12): 2733 (first record from Ottawa Valley, Que.)

Sculpin, spotfin (*Icelinus tenuis*) (lesser filamented sculpin)
J 25(12): 2665 (associations with other fishes off Oregon coast)
T 11 (in B.C. experimental midwater trawling)

Sculpin, tadpole (*Psychrolutes paradoxus*)
T 11 (in B.C. experimental midwater trawling)

Sculpin, thornback (*Paricelinus hopliticus*)
J 25(12): 2665 (associations with other fishes off Oregon coast)
T 11 (in B.C. experimental midwater trawling)

Sculpin, threadfin (*Icelinus filamentosus*)
J 25(12): 2665 (associations with other fishes off Oregon coast)

Sculpins (general)
T 7, 11, 22, 46, 56, 62, 81 (in B.C. experimental or commercial trawling)

Scyliorhinus stellaris
S 1244 (a corticosteroid 1α-hydroxylase in interrenal tissue)

Scyllium canicula (*see* Dogfish (European))

Scyphozoa
T 43 (on Irish moss)

Sea bass, black (*Centropristes striatus*)
J 25(8): 1739 (spinal ganglia position re taxonomy)

Sea butterfly (*Clione limacina*)
CNG 84 (popular description)

Sea cucumbers (*see also* Holothurians)
J 25(9): 1803 (caloric content of *Cucumaria frondosa*)

Sea lion (*Imagotaria downsi*)
J 25(9): 1843 (new genus & species of fossil)

Sea perch (*see* Seaperch)

Sea water (*see also* Oceanography; Salinity; Temperature of natural waters, etc.; *also* next heading)
B 167 (practical handbook of seawater analysis)
S 1234 (H_2O–NaCl–Na_2SO_4 system isopiestic measurements)

Sea water, refrigerated (for holding fishery products)
A 77 (brief summary of use)

Seal, grey (*Halichoerus grypus*)
S 1202 (population, breeding, dispersal, & economy in E Canadian waters)
1228 (isoprenoid fatty acids of blubber fat, re feed)
A 108 (tagging with cattle ear tags)

Seal, harbour (eastern Pacific) (*Phoca vitulina richardi*)
J 25(12): 2749 (possible effect of bounty re Atl. cod codworm infestation)
B 162 : 83 (sockeye salmon predator)

Seal, harbour (western Atlantic) (*Phoca vitulina concolor*)
S 1220 (re Pinnipedia phylogeny)
1226 (fatty acids positional distribution in blubber triglycerides)

Seal, harp (*Pagophilus groenlandicus*)
J 25(11): 2419 (depot fat & milk lipids fatty acid composition)
S 1203 (positional distribution of monoenoic fatty acids in blubber triglycerides)
1220 (re Pinnipedia phylogeny)
1226 (fatty acids positional distribution in blubber triglycerides)
1228 (isoprenoid fatty acids of blubber fat, re feed)
A 108 (1966 Canadian ICNAF studies: commercial catches; tagging)

Seal, hooded (*Cystophora cristata*)
J 25(11): 2419 (depot fat & milk lipids fatty acid composition)
A 108 (1966 Canadian ICNAF studies: commercial catches; hunting mortality)

Seals (general)
J 25(11): 2419 (fatty acids composition of commercial oils)

Seaperch, striped (*Embiotoca lateralis*)
J 25(8): 1651 (plasma protein-bound inorganic iodide)
(11): 2519 (marking by high-frequency electric sparks)

Seaperches (*see* Seaperch, striped; *also* Perch species)

Searcher (*Bathymaster signatus*)
T 81 (in experimental B.C. groundfish trawling)

Seaweeds (*see also* Algae; Dulse; Irish moss; *and* names of other types)
S 1239 (sterols in red)

Sebastes marinus (*mentella*) (*see* Redfish)

Sebastes mentella (*see* Redfish)

Sebastodes aleutianus (*see* Rockfish, blackthroat)

Sebastodes alutus (*see* Perch, Pacific ocean)

Sebastodes aurora (*see* Rockfish, aurora)

Sebastodes brevispinis (*see* Rockfish, silvergray)

Sebastodes caurinus (*see* Rockfish, copper)

Sebastodes ciliatus (*see* Rockfish, dusky)

Sebastodes crameri (*see* Rockfish, blackmouth)

Sebastodes diploproa (*see* Rockfish, splitnose)

Sebastodes elongatus (*see* Rockfish, greenstriped)

Sebastodes entomelas (*see* Rockfish, widow)

Sebastodes flavidus (*see* Rockfish, yellowtail)

Sebastodes goodei (*see* Chilipepper)

Sebastodes helvomaculatus (*see* Rockfish, rosethorn)

Sebastodes jordani (*see* Rockfish, shortbelly)

Sebastodes levis (*see* Rockfish, cow)

Sebastodes maliger (*see* Rockfish, quillback)

Sebastodes melanops (*see* Rockfish, black)

Sebastodes melanostomus (*see* Rockfish, blackgill)

Sebastodes miniatus (*see* Rockfish, vermilion)

Sebastodes mystinus (*see* Rockfish, blue)

Sebastodes nebulosus (*see* Rockfish, China)

Sebastodes nigrocinctus (*see* Rockfish, tiger)

Sebastodes paucispinis (*see* Bocaccio)

Sebastodes pinniger (*see* Rockfish, canary)

Sebastodes polyspinis (*see* Rockfish, northern)

Sebastodes proriger (*see* Rockfish, redstripe)

Sebastodes reedi (*see* Rockfish, yellowmouth)

Sebastodes ruberrimus (*see* Snapper, red)

Sebastodes rubrivinctus (*see* Rockfish, flag)

Sebastodes saxicola (*see* Rockfish, stripetail)

Sebastodes wilsoni (*see* Rockfish, pigmy)

Sebastodes zacentrus (*see* Rockfish, sharpchin)

Sebastolobus (species)
T 34 (systematics)

Sebastolobus alascanus (*see* Rockfish, spinycheek)

Sebastolobus altivelis (*see* Rockfish, longspine channel)

Sediments
J 25(6): 1181 (of upper Great Lakes, re benthic environment subdivisions)
(11): 2327 (Fe, Mn, & Ti in St. Lawrence R. estuarial)
(12): 2665 (associations of Oregon coast fishes with types of)
S 1223 (re seasonal variations in marine benthos feed availability)
A 108 (1966 Canadian ICNAF studies)

Seki, Humitake
J 25(4): 625 (organic matter production and mineralization)

Selectivity of fishing gear
J 25(10): 2123 (underwater observation of scallop drag)

Semakula, S. N.
J 25(12): 2589 (Fraser R. white sturgeon)

Semotilus atromaculatus (*see* Chub, creek)

Sergeant, David Ernest
S 1200 (age determination of land mammals from annuli)

Sergeant major (*see* Convict fish)

Sergestes similis (a sergestid shrimp)
J 25(7): 1311 (pressure effect on respiration of vertically migrating)

Seriola dorsalis (*see* Yellowtail)

Serology (*see also* Blood)
B 162 : 380 (re sockeye salmon stocks identification)
0
S 1204 (serum transferrins polymorphism of scombrids re population units)

Serrivomer jesperseni (*see* Eel, snipe)

Serum (*see* Blood; Serology)

Sex determination
J 25(4): 813 (of brown & related trouts by anal fin dimorphism)

Sex ratio
J 25(7): 1377 (changes in L. Superior lake trout)
(9): 1813 (F) ("giant" smelts of Heney L., Que.)
(10): 2091 (lake whitefish, Lac la Ronge, Sask.)
B 162 : 284 (seaward migrating sockeye salmon)
CNS 26 (in B.C. chum salmon catches, 1957–63)
T 10 (of sockeye salmon, 1965 & 1966 spawning run escapement to Lakelse L., B.C.)
16 (of Pac. ocean perch in experimental catches, 1966)
S 1206 (of salmon from Labrador Sea & off W Greenland)

Sexual maturity (*see* Maturation)

Shad, American (*Alosa sapidissima*)
J 25(4): 667 (re Great Lakes species succession & exploitation)
T 7, 22, 56, 81 (in experimental & commercial B.C. trawling)

Shark (a SW England coast) (*see Scyliorhinus stellaris*)

Shark, blue (*Prionace glauca*)
J 25(4): 825 (feeding behaviour in NE Pac.)
S 1244 (a corticosteroid 1α-hydroxylase in interrenal tissue)

Shark, brown cat (*Apristurus brunneus*)
T 22, 81 (in experimental B.C. groundfish trawling)

Shark, dogfish (*see* Dogfish)

Shark, dusky (*Carcharhinus obscurus*)
S 1244 (a corticosteroid 1α-hydroxylase in interrenal tissue)

Shark, hammerhead (*see* Hammerhead)

Shark, mako (*see* Mako)

Shark, nurse (*Ginglymostoma cirratum*)
J 25(7): 1441 (attraction with pulsed low-frequency sound)

Shark, reef (*Carcharhinus* species)
J 25(7): 1441 (attraction with pulsed low-frequency sound)

Shark, sharpnose (*Rhizoprionodon* species)
J 25(7): 1441 (attraction with pulsed low-frequency sound)

Shark, sickle (*Carcharhinus falciformis*)
S 1244 (a corticosteroid 1α-hydroxylase in interrenal tissue)

Shark, soupfin (*Galeorhinus zyopterus*)
J 25(4): 825 (feeding behaviour in NE Pac.)

Sheepshead (*Aplodinotus grunniens*) (drum)
J 25(1): 169 (pesticide residues in meals & oils)
S 1226 (fatty acids positional distribution in fat triglycerides)
A 85 (nutrient composition of meal as poultry feed)

Sheldon, Raymond Wilfred
S 1223 (food availability seasonal variations for benthos)

Shell (*see also* Clam; Exoskeleton; Mollusca; Oyster)
S 1199 (borer attack on ancient Sable Is. oyster & scallop)

Shellfish occasional toxicity
S 1256 (experimentally induced in rough whelk)

Shepard, Michael Perry
S 1230 (spawning populations of N Pac. salmon)

Sheri, Ahmad Nadum
J 25(10): 2225 (Bay of Quinte white perch)

Shieh, Hang-shan
S 1229 (^{14}C-labelled betaine enzymic oxidation by *Achromobacter cholinophagum*)

Shiner, common (*Notropis cornutus*)
J 25(6): 1199 (low temperature effects on feeding in 3 Ont. localities)

Shiner, emerald (*Notropis atherinoides*)
J 25(4): 667 (re Great Lakes species succession & exploitation)

Shiner, golden (*Notemigonus crysoleucas*)
J 25(6): 1199 (low temperature effects on feeding in 3 Ont. localities)
(8): 1739 (spinal ganglia position taxonomy)

Shiner, redside (*Richardsonius balteatus*)
J 25(1): 81 (limnology re mortality in 3 SW B.C. lakes)
(7): 1317 (muscle proteins inheritance in hybrids with peamouth chub)

Shipworm (*Teredo navalis*)
CSG 53 (new treatment to combat)
T 21 (tin compound for combating)
A 114 (same as CSG 53 above)

Shoop, Clifford Thomas
A 93 (Atl. lobsters in B.C. waters)

Shrimp, humpback (*Pandalus hypsinotus*) (king shrimp)
CNG 85 (1967 prospecting for, in B.C.)
T 30 (in B.C. experimental groundfish trawling)
A 104 (based on CNG 85 above)

Shrimp, pink (*Pandalus borealis*)
J 25(2): 267 (occurrence & retention of thetin derivative from feed)
CHN 33 (suggestions for commercial handling)
34 (re 1968 Maine shrimp industry)
CNG 85 (1967 prospecting for, in B.C.)
T 18 (catches in Gulf of Alaska & Bering Sea exploratory fishing, 1957–64)
61 (in B.C. exploratory fishing, 1966 & 1967)
22, 30, 81 (in B.C. experimental groundfish trawling)
S 1260 (adaptation re striped pink shrimp in NW Atl.)
A 89 (same as CHN 33 above)
104 (based on CNG 85 above)

Shrimp, sidestripe (*Pandalopsis dispar*) (giant red shrimp)
CNG 85 (1967 prospecting for, in B.C.)
T 18 (catches in Gulf of Alaska & Bering Sea exploratory fishing, 1957–64)
22, 30, 81 (in B.C. experimental groundfish trawling)
61 (in B.C. exploratory fishing, 1966 & 1967)
A 104 (based on CNG 85 above)

Shrimp, smooth pink (*Pandalus jordani*)
CNG 85 (1967 prospecting for, in B.C.)
T 30 (in B.C. experimental groundfish trawling)
61 (in B.C. exploratory fishing, 1966 & 1967)
A 104 (based on CNG 85 above)

Shrimp, striped pink (*Pandalus montagui*)
J 25(9): 1803 (caloric content)
CHN 33 (suggestions for commercial handling)
S 1260 (adaptation re pink shrimp in NW Atl.)
A 89 (same as CHN 33 above)

Shrimps (in general) (*see also Argis*; Prawn; *Sergestes*)
CNG 85 (1967 prospecting for, in B.C.)
T 18 (exploration in Gulf of Alaska & Bering Sea, 1957–64)
30 : 23 (in B.C. experimental groundfish trawling)
S 1260 (adaptation among NW Atl. species)
A 104 (based on CNG 85 above)

Shumway, Dean Lee
J 25(1): 49 (dissolved O_2 & CO_2 on bass & salmon swimming)

Sibbaldus musculus (*see* Whale, blue)

Sicklefish (*Drepane punctata*) (concertinafish)
J 25(1): 197 (microorganisms isolated from diseased)

Siegesmund, Kenneth August
J 25(5): 863 (trout cornea ultrastructure)

Sight (*see also* Eye; Light, reactions to)
J 25(5): 867 (role of, in homing chinook salmon)

Silicate
J 25(12): 2739 (NE Pac. Ocean surface distributions)
B 167 : 65, 137 (determination in sea water)

Silt (*see* Sediments)

Simard, André
J 25(7): 1501 (F) (*S. namaycush* in marine waters)
(9): 1831 (F) (*Esox masquinongy*)

Simon, Raymond Charles
J 25(3): 473 (salmon blood lactate after exercise)

Simpson, Sylvia Geraldine
J 25(4): 817 (redfish muscle hypoxanthine accumulation)

Sinclair, Donald Coll
J 25(9): 1997 (*Cottus asper* limnetic occurrence)

Sinclair, Ruth Estella
J 25(10): 2071 (haddock preserved by ethylenediaminetetraacetic acid)
T 67 (volumetric determination of EDTA)
68 (colorimetric determination of EDTA salts on haddock, cod, & flounder)

Siphonophora
T 55 : 17 (identification of B.C.)

Sipos, John Charles
J 25(8): 1561 (jellyfish fatty acids)

Sipunchuloidea
T 25, 35, 59, 60, 73 (in Strait of Georgia benthos biomass)

Size (*see also* Age; Growth; Length; Weight)
CNS 26 (composition of B.C. chum salmon catches, 1957–63)
T 10 (composition of sockeye salmon 1965 & 1966 spawning run escapement to Lakelse L., B.C.)
16, 81 (composition of Pac. ocean perch experimental catches)
S 1235 (mathematics of quick methods for estimating size limit changes effect on catches)
A 99 (& age composition of Atl. cod)

Skate (a SW England coast) (*see Raja clavata*)

Skate (an Oregon coast) (*see Psammobatis spinosissimus*)

Skate, barndoor (*Raja laevis*)
S 1226 (fatty acids positional distribution in liver triglycerides)
1244 (a corticosteroid 1α-hydroxylase in interrenal tissue)

Skate, big (*Raja binoculata*)
J 25(8): 1651 (plasma protein-bound inorganic iodide)
(12): 2665 (associations with other Oregon coast fishes)
T 7, 56 (in commercial B.C. groundfish trawling)
A 91 (observed in B.C. landings of fish for mink feed)

Skate, black (*Raja kincaidi* (*i*))
J 25(12): 2665 (associations with other coast fishes)

Skate, little (*Raja erinacea*)
S 1244 (a corticosteroid 1α-hydroxylase in interrenal tissue)

Skate, longnose (*Raja rhina*)
T 7, 56 (in commercial B.C. groundfish trawling)
A 91 (observed in B.C. landings of fish for mink feed)

Skate, roughtail (*Raja trachura*)
J 25(12): 2665 (associations with other coast fishes)

Skate, starry (*Raja stellulata*)
T 7, 56 (in commercial B.C. groundfish trawling)
A 91 (observed in B.C. landings of fish for mink feed)

Skate, thorny (*Raja radiata*)
J 25(12): 2549 (1α-hydroxycorticosterone function)
S 1205 (biological activity of interrenal 1α-hydroxycorticosterone)
1244 (corticosteroid 1α-hydroxylase of interrenal tissue)

Skate, winter (*Raja ocellata*)
S 1205 (biological activity of interrenal 1α-hydroxycorticosterone)

Skates (general)
T 11, 22, 30, 46, 81 (in experimental B.C. groundfish trawling)

Skeena River, B.C. (*see also* Salmon)
S 1230 (spawning populations of sockeye & other salmons)

Skin (*see also* Pelage; Pelts; Scales)
J 25(3): 611 (guanidine compounds induction of pallor in young salmonids)
(9): 1797 (dieldrin accumulation in goldfish, after aldrin ingestion)
(9): 1901 (guanine & hypoxanthine formation in Atl. salmon)
(11): 2403 (guanine level changes during coho salmon development)
S 1258 (proteolytic pseudomonad from rainbow trout lesions)

Skipjack (tuna) (*see* Tuna, skipjack)

Skipjack, black (*Euthynnus lineatus*)
J 25(9): 1987 (red & white muscle temperature of recently caught)

Skull (*see* Cranium; Teeth)

Slavin, Joseph William
J 25(2): 299 (refrozen cod storage quality)

Slope waters (*see* Hydrography; Oceanography)

Small, Lawrence Frederick
J 25(7): 1311 (pressure re crustacean respiration)
(11): 2461 (^{65}Zn in marine crustaceans)

Smelt, "giant" and "dwarf" American (*Osmerus eperlanus mordax*)
J 25(9): 1813 (F) (sympatric populations in Heney L., Que.)

Smelt, surf (*Hypomesus pretiosus* (*pretiosus*))
J 25(1): 203 (range extension in Alaska, as *H. p. pretiosus*)
T 46, 62 (in experimental B.C. groundfish trawling)

Smith, Charlie Edward
J 25(1): 151 (coho hematological changes)

Smith Inlet, B.C. (*see also* Salmon)
S 1230 (spawning populations of sockeye & other salmons)

Smith, James Benson
J 25(11): 2257 (L. Manitou, Ont., marked lake trout survival)

Smith Lake, Alaska
J 25(10): 2101 (atmospheric & inorganic N utilization by algae)

Smith, Michael Stuart
CNG 85 (1967 B.C. coast shrimp exploration)
T 61 (shrimp sampling & temperature data off B.C., 1966 & 1967)
S 1245 (protamine biosynthesis)
1246 (nucleotide synthesis)
1247 (nucleotide synthesis)
A 104 (good shrimping areas discovered)

Smith, Morden Whitney
J 25(2): 209 (pond formation re brook trout catches)
(10): 2011 (fertilization & predator control on trout)

Smith, Stanford Henry
J 25(4): 667 (Great Lakes species succession & fishery exploitation)

Smoking
B 166 : 41 (American eels in Canada)

Smolt (*see* Salmon, Atlantic; *also* species of Pacific salmons)

Smoothhead (*Alepocephalus convexifrons*)
J 25(12): 2665 (associations with other coast fishes)

Smoothtongue, California (*Leuroglossus stilbius*)
T 11, 62 (in B.C. experimental trawling)

Snailfish, blacktail (*Careproctus melanurus*)
J 25(12): 2665 (associations with other fishes off Oregon coast)

Snailfish, slipskin (*Liparis fucensis*)

Snailfishes (general)
T 11, 22, 30, 46, 81 (in B.C. experimental trawling)

Snails, marine (*see* Clam drill; Gastropoda)

Snake (*see* Venom)

Snapper, mutton (*Lutjanus analis*)
J 25(7): 1441 (attraction with pulsed low-frequency sound)

Snapper, red (*Sebastodes ruberrimus*) (rasphead rockfish)
J 25(11): 2477 (proteins electropherograms re rockfishes systematics)
T 7, 11, 22, 46, 56, 62, 81 (in experimental or commercial B.C. trawling)

Snapper, yellowtail (*Ocyurus chrysurus*)
J 25(7): 1441 (attraction with pulsed low-frequency sound)

Sodium compounds (*see also* Salt)
J 25(7): 1475 (Na uptake in tripolyphosphate-dipped Atl. cod muscle)
S 1234 (activity coefficient of H_2O–NaCl–Na_2SO_4 system re sea water)
A 85 (in freshwater fishmeals)

Sole, butter (*Isopsetta isolepis*)
J 25(5): 1077 (range extension into Bering Sea)
(8): 1743 (fertilized eggs: observations on)
(12): 2665 (associations with other fishes off Oregon coast)
A 91 (1951–66 B.C. landings for mink feed)
T 7, 19, 56, 62, 81, 89 (in experimental or commercial B.C. trawling)

Sole, C-O (*Pleuronichthys coenosus*)
J 25(8): 1651 (plasma protein-bound inorganic iodide)
A 91 (observed in B.C. landings of fish for mink feed)
T 7, 56, 62 (in experimental or commercial B.C. trawling)

Sole, curlfin (*Pleuronichthys decurrens*)
J 25(12): 2665 (associations with other fishes off Oregon coast)
A 91 (observed in B.C. landings of fish for mink feed)
T 7, 22, 30, 56, 62, 81 (in experimental or commercial B.C. trawling)

Sole, deepsea (*Embassichthys bathybius*)
J 25(12): 2665 (associations with other fishes off Oregon coast)

Sole, Dover (*Microstomus pacificus*)
J 25(12): 2665 (associations with other fishes off Oregon coast)
T 7, 11, 19, 22, 30, 46, 56, 62, 81, 89 (in B.C. experimental or commercial trawling)
A 91 (observed in B.C. landings of fish for mink feed)

Sole, English (*Parophrys vetulus*) (Pacific lemon sole)
J 25(3): 495 (salinity & temperature effects on development & survival)
(8): 1539 (postmortem glycogen & starch degradation in muscle)
(8): 1745 (flesh homogenate as substrate for experimental growth of *Clostridium botulinum*)
(8): 1753 (preservatives effects on flesh)
(10): 2237 (subcutaneous dart tag)
(11): 2519 (marking by high-frequency electric sparks)
T 7, 11, 19, 22, 30, 46, 56, 62, 81, 89 (in B.C. experimental or commercial trawling)
19 : 27 (experimental egg hatching)
A 91 (observed in B.C. landings of fish for mink feed)

Sole, flathead (*Hippoglossoides elassodon*)
T 7, 11, 22, 30, 46, 56, 62, 81 (in B.C. experimental or commercial trawling)
34 (distribution, stocks, populations, synonymy, systematics)
A 91 (observed in B.C. landings of fish for mink feed)

Sole, forkline (*Inopsetta ischyra*)
J 25(8): 1539 (postmortem muscle glycogen & starch degradation)

Sole, lemon (Pacific) (*see* Sole, English)

Sole, petrale (*Eopsetta jordani*) ((Pacific) Brill)
J 25(12): 2665 (associations with other fishes off Oregon coast)
T 7, 11, 19, 22, 30, 46, 56, 62, 81, 89 (in B.C. experimental or commercial trawling)
19 : 28 (experimental egg hatching)
41 (embryonic development)
A 91 (observed in B.C. landings of fish for mink feed)

Sole, rex (*Glyptocephalus zachirus*)
J 25(12): 2665 (associations with other fishes off Oregon coast)
T 7, 11, 19, 22, 30, 46, 56, 62, 81, 89 (in B.C. experimental or commercial trawling)
A 91 (observed in B.C. landings of fish for mink feed)

Sole, rock (*Lepidopsetta bilineata*)
J 25(12): 2665 (associations with other fishes off Oregon coast)
T 7, 11, 19, 22, 30, 46, 56, 62, 81, 89 (in B.C. experimental or commercial trawling)
34 (distribution, stocks, populations, synonymy, systematics)
36 (NE Pac. growth rate comparisons)
A 91 (observed in B.C. landings of fish for mink feed)

Sole, sand (*Psettichthys melanostictus*)
T 7, 22, 30, 46, 56, 62, 81 (in experimental or commercial B.C. trawling)
A 91 (observed in B.C. landings of fish for mink feed)

Sole, slender (*Lyopsetta exilis*)
J 25(12): 2665 (associations with other fishes off Oregon coast)
T 7, 11, 22, 30, 46, 56, 81 (in B.C. experimental or commercial trawling)
A 91 (observed in B.C. landings of fish for mink feed)

Sole, yellowfin (*Limanda aspera*) (yellowfin flounder)
T 7, 56, 62, 89 (in experimental or commercial B.C. trawling)
A 90, 103 (Japan & USSR Bering Sea fishery)
91 (observed in B.C. landings of fish for mink feed)

Solubles, condensed
A 98 (Pac. herring, re Atl. herring use)

Sound, reactions to
J 25(6): 1155 (Atl. cod)
(7): 1441 (fish attraction to pulsed low-frequency sound)

Sound, ultrasonic
J 25(3): 605 (backscatter effect as quality test for fresh & frozen flesh)

Sound-scattering layers (*see* Sounding, echo)

Sounding, echo
J 25(3): 457 (B.C. coast sound-scattering layers re midwater trawl catches)
(11): 2349 (for direct estimation of hake populations)
T 11 (B.C. coast sound-scattering layers re midwater trawl catches)

Sounding response of fish
J 25(6): 1115 (response of kokanee & sockeye salmon)

Southcott, Burnett Anne
J 25(8): 1745 (fish homogenates as substrates)
(8): 1753 (ethylenediaminetetraacetic acid & chlortetracycline in fish preservation)

Spangler, George Russell
J 25(6): 1145 (*Esox masquinongy* harvest & mortality)

Sparrow, Roger Arthur Hugh
J 25(3): 599 (B.C. freshwater chum)

Spawning (*see also* Eggs, fish; Fecundity; Life history; Migration; etc.)
J 25(3): 485 (behaviour & distribution of sockeye salmon on Alaska lake beaches)
(5): 867 (odour & vision role in chinook salmon choice of site)
(10): 2143 (orientation of American eels toward spawning area)
(11): 2439 (history of Atl. salmon from scales)
(12): 2589 (Fraser R., B.C., white sturgeon)
B 162 (several chapters on habits, etc. of sockeye salmon)
165 : 2 (carp)
CJG 14, 15 (Nfld. herring)
CNG 86 (B.C. 1968 herring)
T 10 (age, size, & sex composition of 1965 & 1966 sockeye salmon escapement to Lakelse L., B.C.)
S 1230 (populations of Canadian N Pac. salmons)
1255 (NW Atl. capelin)
A 102 (B.C. herring: 1967 scanty spawning)
105 (miles of B.C. herring spawn re catches, 1955–67)
108 (1966 Canadian ICNAF studies on various Atl. fishes)

Spearing
B 166 : 21 (eels)

Spears, Doris Mae
J 25(4): 639 (heavy metal ions & fish muscle rancidity)

Speciation (*see also* Key; Phylogeny)
J 25(2): 415 (kokanee vs. anadromous sockeye salmon)
(5): 877 (*Halargyreus johnsonii* vs. *H. brevipes* & *H. affinis*)
(5): 943 (N American Atl. & arctic coasts *Anonyx* Amphipoda)
(7): 1323 (lactate dehydrogenase differentiation in trouts)
(9): 1843 (sea lions)
(11): 2477 (protein electropherograms of 33 rockfish species)

Species, new
J 25(2): 321 (*Chondracanthus irregularis* & *Acanthochondria holocephalarum* parasitic copepods from B.C. fishes)
(5): 943 (*Anonyx sarsi* as distinct from similar *Anonyx*)
(7): 1423 (*Taeniopteryx burksi*, *T. lonicera*, *T. metequi*, & *T. ugola* stoneflies)
(7): 1509 (*Cyclopecten carlottensis* from NE Pac.)
(9): 1843 (& genus of fossil sea lion, *Imagotaria downsi*)

(11): 2269 (*Stomachetosella hincksi* bryozoan, arctic Canada)
(11): 2365 (*Gyrocotyle major* & *G. abyssicola* tapeworms)

Species, new records or range extensions of
J 25(1): 181 (2 *Macdonaldia challengeri* specimens from NE Pac. Ocean)
(1): 203 (surf smelt in W Alaska)
(1): 205 (*Lumbricus* earthworm species records from near Vancouver, B.C.)
(2): 347 (hippolytid & crangonid shrimps, Queen Elizabeth Is., Canadian arctic)
(2): 421 (longnose greeneye N to N.S.)
(5): 1075 (NW Atl. extension for pelagic stingray)
(5): 1077 (butter sole extension in Bering Sea)
(7): 1423 (eastern N American *Taeniopteryx* stoneflies)
(7): 1501 (F) (lake trout in E Canadian arctic marine or saline waters)
(8): 1644 (*Cyphocaris bowieri* amphipod to NE Greenland waters)
(11): 2269 (8 Bryozoa species in arctic Canada)
(11): 2509 (3 rockfish species new to B.C.)
(12): 2707 (new *Conchoderma virgatum* barnacle records in NW Atl.)
(12): 2721 (Greenland halibut in Bay of Fundy)
(12): 2733 (first Que. records of spoonhead & deepwater sculpins)
T 30 : 4 (*Spirontocaris sica* shrimp to northern B.C.)

Species group analysis of assemblages
J 25(7): 1405 (recurrent, of Gulf of Guinea demersal fish)

Species succession
J 25(4): 667 (& fishery exploitation in Great Lakes)

Speed of swimming (*see* Swimming)

Sperm (*see also* Testes)
J 25(2): 363; (6): 1295 (frozen preservation of Atl. salmon)
(12): 2623 (cryogenic preservation of Atl. cod)
(12): 2695 (chilled storage effect on sockeye & pink salmon)
S 1231 (uticolytic enzymes in Atl. cod)
1236 (lipids biosynthesis from added substrates by Atl. salmon)
1237 (CO_3 fixation by Atl. cod)
1245 (protamine biosynthesis during steelhead trout spermatogenesis)
1249 (goldfish spermiation as bioassay for salmon gonadotropin)

Sphyraena ensis (*see* Barracuda, Mexican)

Sphyrna (*see* Hammerhead)

Sphyrna lewini (*see* Hammerhead, scalloped)

Spinal cord; Spinal ganglia (*see* Nerve system)

Spirontocaris (hippolytid shrimps)
J 25(2): 347 (Queen Elizabeth Is., Canadian arctic)
T 30 (*S. sica* range extension off B.C.)
S 1260 (adaptation re other shrimps in NW Atl.)

Splake (hybrid of lake trout and brook trout)
J 25(4): 690 (success in Great Lakes)

Spleen
J 25(12): 2643 (furunculosis bacteria in brook trout)

Spores
J 25(3): 547 (*Clostridium botulinum*)

Sport fishing (*see also* Angling)
J 25(7): 1355 (walleye)
B 165 : 60 (carp)
A 108 (statistics re bluefin tuna, 1966)

Sprague, John Booty
S 1196 (copper–zinc mining pollution on spawning salmon)
1241 (aquatic insect DDT tolerance disproved)
1252 (rainbow trout avoid zinc sulphate)
A 84 (water pollution re fisheries of Atl. provinces)

Squalus acanthias (*see* Dogfish)

Squalus suckleyi (*see* Dogfish)

Squawfish, northern (*Ptychocheilus oregonense*)
B 162 : 234 (predator of young sockeye salmon)

Squid (*Loligo opalescens*)
CNG 84 (popular description)
T 7, 56, 62 (in B.C. experimental or commercial trawling)

Squid (*Omnastrephes sloani pacificus*)
CHN 32 (used in Japanese fish paste)

Squid, arctic (*Gonatus fabricii*)
S 1206 (as feed of northern Atl. salmon)

Squid, short-finned (*Illex illecebrosus* (*illecebrosus*))
J 25(5): 910 (as swordfish feed in NW Atl.)
CJG 15 : 29 (drying in Nfld.)
S 1226 (fatty acids positional distribution in liver triglycerides)
A 108 (1966 Canadian ICNAF studies: commercial catches)

Squires, Hubert Jacob
J 25(2): 347 (decapod Crustacea)
(9): 1763 (lobster ecdysis)
(12): 2723 (lobsters from 95 fath off Nfld.)

S 1260 (aspects of adaptation in decapod Crustacea)

St. Andrews, N.B.
T 20 (computer programming facilities at Biological Station)
A 82 (F) (marine climate of nearby waters)

St. Lawrence, Gulf of (*see also* Oceanography, Canadian Atlantic Coast)
J 25(3): 555 (analysis of cod population in southern)
(12): 2749 (possible effect of harbour seal bounty re Atl. cod codworm infestation)
T 26 (1965 summer oceanography of southern)
80 (fish stocks)
A 82 (F) (marine climate)

St. Lawrence River, Que.
J 25(11): 2327 (Fe, Mn, & Ti in estuarial glacial marine sediments)

St. Margaret's Bay, N.S.
J 25(9): 1803 (caloric content of benthic & epibenthic invertebrates)
T 77 (primary productivity measurements, 1967)

Stain marking of fish
J 25(2): 255 (types of stain)

Stanley, Daniel Jean
S 1199 (ancient oyster & bay scallop shells from Sable Is.)

Starch
J 25(6): 1269 (origin, description, & fate, in oceanic waters)
(8): 1539 (postmortem degradation in fish muscle)

Starfish (*see also* Echinoderms; Ophiuroidea)
J 25(9): 1803 (caloric content of *Asterias vulgaris* & *Ctenodiscus crispatus*)

Starostka, Victor Joseph
J 25(8): 1741 (water core plankton sampler)

Starsnout, bigeye (*Asterotheca pentacantha*)
J 25(12): 2665 (associations with other fishes off Oregon coast)

Starsnout, spinycheek (*Asterotheca infraspinata*)
J 25(12): 2665 (associations with other fishes off Oregon coast)
T 11 (in B.C. experimental midwater trawling)

Starvation (*see also* Stress)
J 25(8): 1555 (effects on rainbow trout blood & muscle)
(11): 2443 (effects on resistance of DDT-fed brook trout)

Stations, Fisheries Research Board of Canada
R 1965–1966: 13–110 (review of programs; lists of scientific staff)
MSP 10 : 17 (list, with addresses)

Statistics (*see* Fisheries; Mathematical treatment)

Steele, Donald Harold
J 25(5): 943 (NA Atl. & arctic coast amphipoda)
T 47 (tabular data from *Anonyx* species)

Steer (*Bos taurus*)
J 25(8): 1651 (plasma protein-bound inorganic iodide)

Stenella graffmani (*see* Dolphin, Pacific spotted)

Stenella longirostris (*see* Dolphin, spinner)

Stenodus leucichthys (*see* Inconnu)

Stephens, Kenneth
S 1223 (food availability seasonal variations for benthos)

Steroids; Sterones (*see also* Cortisol; Hormones)
J 25(12): 2549 (1α-hydroxycorticosterone function in skate)
S 1251 (recovery of microquantities of steroids after thin-layer chromatography)

Sterols; Sterol esters (*see also* Lipids)
J 25(10): 2083 (fatty acids distribution in Atl. cod flesh)
S 1239 (of red seaweeds)

Stevenson, James Cameron
B 162, 164, 167 (Editor's foreword)

Stewart, James Edward
J 25(3): 607 (hemolymph characteristics of *Cancer irroratus*, *C. borealis*, & *Hyas coarctatus*)
(4): 695 (*Gaffkya homari* interaction with *Homarus americanus* defense mechanisms)
(4): 795 (*Gaffkya homari* pathogenicity for *Cancer irroratus*)
(9): 1763 (lobster ecdysis)

Stewart, Kenneth William
J 25(5): 1091 (permanent dry-mounted teleost chromosomes)

Stewart, Nelson Eugene
J 25(8): 1621 (Sevin effects on clams)

Stickleback, blackspotted (*Gasterosteus wheatlandi*)
J 25(12): 2703 (reproductive isolating mechanisms)

Stickleback, brook (*Eucalia inconstans*)
J 25(6): 1199 (low temperature effects on feeding in 3 Ont. localities)

Stickleback, ninespine (*Pungitius pungitius*)
J 25(4): 667 (re Great Lakes species succession & exploitation)

Stickleback, threespine (freshwater) (*Gasterosteus aculeatus*)
B 162 : 235 (as food competitor of young sockeye salmon)

Stickwater
A 98 (Pac. herring, re Atl. herring use)

Stingray, pelagic (*Dasyatis violacea*)
J 25(5): 1075 (range extension in NW Atl.)
S 1244 (a corticosteroid 1α-hydroxylase in interrenal tissue)

Stizostedion canadense (*see* Sauger)

Stizostedion vitreum vitreum (*see* Walleye)

Stocks (*see also* Populations; Rehabilitation; *also* names of organisms)
J 25(7): 1389 (changes in L. Superior juvenile lake trout)
(12): 2701 (simplified computation of recruitment rates)
B 162 (sockeye salmon)
T 31 (recruitment in Atl. mackerel)
58 (Nfld. herring, re catches)
80 (of N.S. Banks & Gulf of St. Lawrence fishes)
S 1230 (of Canadian N Pac. spawning salmons)
A 102, 105 (recent changes in B.C. herring)

Stoddard, Judith Helen
T 5 (herring condition (fatness))

Stomach contents (*see also* Feed)
J 25(7): 1505 (wet vs. dry weight determination methods for walleye)
(9): 1797 (dieldrin accumulation in goldfish, after aldrin ingestion)

Stoneflies
J 25(7): 1423 (E N American *Taeniopteryx*: keys; synonymy; descriptions; distribution records; 4 new species)
S 1241 (disproval of tolerance to DDT insecticide)

Strait of ... (*see* name of strait)

Strandings
S 1240 (distribution of Cuvier's beaked whales in NE Pac.)

Stress (*see also* Activity)
J 25(3): 473 (re blood lactate concentration in salmons)
(9): 1983 (rainbow trout fingerlings reaction to thermal)
(11): 2443 (DDT effect on resistance of brook trout to)
(12): 2549 (interrenalectomy re skate blood components)
S 1260 (thermal, re decapods adaptation)

Strontium compounds
J 25(7): 1333 (lactate in diet for marking goldfish by incorporation into scales)
A 85 (in freshwater fishmeals)

Strickland, John Douglas Hipwell
B 167 (seawater analysis handbook)

Stockner, John Gary
J 25(10): 2037 (thermal stream algal growth)

Strasdine, George Alfred
J 25(3): 547 (*Clostridium botulinum* growth)

Sturgeon (European) (*Acipenser sturio*)
J 25(12): 2711 (muscle creatine kinase localization)

Sturgeon, green (*Acipenser medirostris*)
T 7, 56 (in commercial B.C. trawling)

Sturgeon, lake (*Acipenser fulvescens*)
J 25(4): 667 (re Great Lakes species succession & exploitation)
(7): 1511 (age & growth in Sask. R. delta)

Sturgeon, white (*Acipenser transmontanus*)
J 25(12): 2589 (age, growth, food, & fishery yield, of Fraser R.)
T 7, 56 (in commercial B.C. trawling)

Sturgeon Lake, Ont.
J 25(6): 1145 (maskinonge angling harvest re mortality)

Sucker, largescale (*Catostomus macrocheilus*)
J 25(1): 101 (hybridization with white sucker; morphometry)

Sucker, longnose (*Catostomus catostomus*)
T 33 (in Great Slave L. fishery)

Sucker, white (*Catostomus commersoni* (common sucker)
J 25(1): 101 (hybridization with largescale sucker; morphometry)
(6): 1199 (low temperature effects on feeding in 3 Ont. localities)
(8): 1651 (plasma protein-bound inorganic iodide)
T 33 (in Great Slave L. fishery)

Suckers
J 25(4): 667 (*Catostomus* & *Moxostoma* re Great Lakes species succession & exploitation)

Sugars (*see also* Carbohydrates; Glucose)
J 25(8): 1539 (postmortem degradation of muscle glycogen to)
S 1197 (aldolase activity in marine planktonic algae re their phylogeny)

Sulphur compounds (*see also* Thetin derivatives)
B 167 : 41 (seawater sulphides determination)

Superior, Lake (*see also* Apostle Islands; Great Lakes; Nipigon Bay)
A 106 (transplants of *Oncorhynchus* salmons into)

Surveys (*see also* Exploration)
T 3 (biotic, of Oozy Creek, P.E.I.)
11 (experimental midwater trawl catches, 1964 & 1965, Queen Charlotte Is. region)
16, 22, 30, 46, 62, 81 (B.C. groundfish trawling)
76 (pre-fertilization benthic, of tidal Ostrea L., N.S.)

Survival (*see also* Life history; Mortality; Predation; *also* names of individual species)
J 25(3): 495 (of early-stage English sole)
(8): 1621 (insecticide effect on cockle clam)
(10): 2165 (Atl. salmon smolts, Little Codroy R., Nfld.)
(10): 2213 (factors affecting marking of Atl. salmon smolts)
(11): 2257 (marked lake trout)

Sutton, Anthony Hubert
J 25(7) : 1475 (cod muscle polyphosphates)

Sweers, Henk Ejgill
J 25(9): 1911 (vertical temperature distribution)

Swim bladder (*see* Bladder, swim)

Swimming; Swimming speed (*see also* Activity)
J 25(1): 49 (dissolved O_2 & CO_2 effect on juvenile largemouth bass & coho salmon)
(5): 837 (effect on Atl. cod muscle & blood lactic acid & glycogen)
(8): 1689 (re goldfish & rainbow trout respiratory quotient)
(10): 2123 (of sea scallops)
MSP 10 : 14 (re water temperature in respirometer)
A 116 (re water temperature in respirometer)

Swordfish (*Xiphias gladius*)
J 25(5): 903 (feed & feeding habits in NW Atl.)
A 108 (1966 Canadian ICNAF studies: commercial catches; weights; tagging; distribution)

Symons, Philip Edward Kyrle
J 25(11): 2387 (Atl. salmon deprived of food)
T 9 (young salmon Pletcher "grow-thru" tags retention)

Sympatry
J 25(9): 1813 (F) ("giant" and "dwarf" smelts of Heney L., Que.)

Synodus (*see* Lizardfishes)

Synonymy (*see* Nomenclature; Taxonomy and systematics)

Systematics (*see* Phylogeny; Speciation; Taxomy and systematics)

Szeplaki, B. J.
J 25(12): 2549 (elasmobranch interrenalectomy & stress)

T

Tables (mathematical)
B 167 (oceanographic)
T 45 ($\varphi = 2 \arcsin \sqrt{X}$)

Tactostoma macropus (*see* Dragonfish, arrow)

Taeniopteryx species (*see* Stoneflies)

Tagging methods, returns, losses, and interpretation (*see also* Marking; Migration)
J 25(1): 177 (harpoon adapted for tagging surface-swimming fish)
(4): 783 (pink salmon with rubber bands for marine mortality estimation)
(7): 1348, 1361 (walleye in Nipigon Bay, Ont.)
(10): 2237, 2247 (subcutaneous "grow-thru" dart tag for fishes)
(11): 2257 (survival of tagged vs. marked lake trout)
B 162 : 13, 373 (sockeye salmon)
T 9 (retention of Pletcher "grow-thru" tags by Atl. salmon)
17 (micromagnetic for pink salmon fry)
31 (Atl. mackerel)
62 (Pac. cod)
74 (sablefish)
S 1218 (Maritime Provinces, 1964–66)
1242 (evaluation of 2 ways of attaching tags to Atl. salmon smolts)

A 86 (returns for ICNAF 1966 Pac. salmons & steelhead trout)
107 (9 species of whales in N Atl., 1966–67)
108 (1966 Canadian ICNAF studies: various species; use of cattle eartags for swordfish)

Tapeworms
J 25 (11): 2365 (2 new species of *Gyrocotyle* (Monogenea))
(11): 2523 (*Triaenophorus nodulosus* in burbot)
B 162 : 94, 378 (*Triaenophorus crassus* & *Eubothrium salvelini* re sockeye salmon stocks identification)
T 48 (parasitic to lampreys)
S 1206 (*Eubothrium crassum* in Atl. salmon)

Tapirfish (*see Macdonaldia challengeri*)

Tarletonbeania crenularis (*see* Lanternfish, blue)

Tarletonbeani taylori (a lanternfish)
J 25(3): 457 (in N B.C. midwater trawl catches)
T 11 (as above)

Tarpon (a tropical) (*see Megalops cyprinoides*)

Tarr, Hugh Lewis Aubrey
J 25(8): 1539 (glycogen & starch degradation)
S 1221 (fish meal supplementation of chicken breeder rations on hatchability)
A 78 (fish bacterial spoilage & its control)
79 (freezing fish)
80 (nutritive value of fish)
97 (herring meal nutritive value)

Taste panels (*see* Flavour; Quality of fishery products)

Tattooing
J 25(10): 2233 (salmonid fingerlings)

Tautog (*Tautoga onitis*)
J 25(8): 1739 (spinal ganglia position re taxonomy)

Taxonomy and systematics (*see also* Nomenclature; Speciation)
J 25(7): 1323 (lactate dehydrogenase re trout speciation)
(8): 1603 (marine phytoplankters fatty acids re taxonomic relations)
(8): 1667 (cytotaxonomic relations of Great Lakes coregonids)
(8): 1739 (re spinal ganglia position in teleosts)
(11): 2269 (93 arctic Canada Bryozoa species)
(11): 2365 (*Gyrocotyle* tapeworms)
(11): 2477 (protein electropherograms of 33 rockfish species re systematics)
B 162 : 1 (sockeye salmon)
T 34 (arrowtooth & spinycheek flounder; rock & flathead sole; Pac. cod)

Taylor, Frank John Rupert
J 25(10): 2241 (parasitism of *Gonyaulax catenella*)

Taylor, Frederick Henry Carlyle
J 25(3): 457 (trawl catches re sound scattering layers)
(3): 589 (herring school behaviour re midwater trawl)
T 11 (Queen Charlotte Sound & Is. midwater trawl catches)
A 105 (what happened to the herring)

Teeth (*see also* Tusk)
S 1200 (annuli for land mammals age determination)

Temperature, reactions to
J 25(1): 9 (re hatchery vs. wild Atl. salmon parr feeding behaviour)
(3): 495 (English sole early development)
(6): 1199 (re Great Lakes fishes feeding)
(6): 1229 (re phytoplankton ecology in an Ont. reservoir)
(8): 1729 (crab & lobster O_2 consumption at low temperature)
(8): 1733 (temperature resistance crabs, crayfish & lobster)
(9): 1901 (effect on Atl. salmon guanine & hypoxanthine formation)
(9): 1983 (physiological interaction among rainbow trout fingerlings)
(10): 2037 (algal growth & primary productivity in a thermal stream)
(10): 2111(effect on coregonids scale annulus formation)
(12): 2717 (upper lethal temperatures at various salinities after acclimation of mummichog & banded killifish)
B 162 : 288 (seaward migrating sockeye salmon)
A 92 (abnormal Atl. affecting herring fishery)

Temperature of natural waters (*see also* Hydrography; Limnology; Oceanography; *also* names of lakes and other bodies of water)
J 25(9): 1911 (mathematical treatment for average vertical, in lakes)
(11): 2427 (recent trends in Gulf of Maine subsurface temperatures)
(12): 2609 (summer stratification, Gulf of Maine)
T 32, 70, 82 (B.C. coast)
54 (charts & bathythermograms, NE Pac. Ocean, 1965 & 1966)
61 (B.C. coastal, during shrimp exploration, 1966 & 1967)
82 (surface, at B.C. lighthouses)
S 1215 (recent trends in NW Atl. Ocean, in ICNAF Subarea 4)
1216 (sea & air temperature anomalies)
A 82 (F) (Gulf of St. Lawrence & waters to SW)

Templeman, Wilfred
J 25(5): 877 (*Halargyreus* from W N Atl. and review)
(11): 2365 (2 new species of *Gyrocotyle*)
S 1206 (Atl. salmon from Labrador Sea and off W Greenland)
1216 (anomalies of Station 27 sea temperature & Torbay St. John's air temperature)
1255 (capelin biology in NW Atl.)
A 108 (Canadian research report)

Tencati, John Robert
J 25(8): 1637 (NE Greenland amphipods)

Tench (*Tinca tinca*)
J 25(12): 2711 (muscle creatine kinase localization)

Teredo navalis (*see* Shipworm)

Terhune, Lorne Donald Bruce
T 85 (free-floating current followers)

Territorialism
J 25(7): 1453 (juvenile chinook salmon & steelhead trout)

Testes (*see also* Sperm)
J 25(9): 1797 (dieldrin accumulation in goldfish, after aldrin ingestion)
(9): 1813 (F) (to body weights of "giant" vs. "dwarf" smelts)
(12): 2643 (furunculosis bacteria in brook trout)
S 1224 (conversion of androstenedione to testosterone by lobster)

Testosterone (*see* Hormones)

Teuthis vermiculatus (*see* Triggerfish)

Texture (*see* Quality of fishery products)

Thais lapillus (*see* Dogwinkle, Atlantic)

Thaleichthys pacificus (*see* Eulachon)

Thawing
J 25(2): 299 (effect on storage quality of refrozen Atl. cod)
(2): 318 (microwave vs. water thawing: engineering considerations)
(3): 605 (ultrasonic effects as quality test for flesh after)
(4): 733 (effects on trap-caught Atl. cod flesh quality)
(5): 829 (effects on drip in American plaice fillets)

Theragra chalcogrammus (*see* Pollock, walleye)

Therapon jarbua (*see* Tigerfish)

Thermophilism
J 25(10): 2037 (algal growth in a thermal stream)

Thetin derivatives
J 25(2): 267 (occurrence & retention in some filter-feeding marine animals)
(11): 2453 (significance of, as precursor of dimethyl sulphide odour of fresh clams)

Thiamin (*see* Vitamin B group)

Thomas, Martin Lewis Hall
J 25(12): 2725 (American lobster overwintering in P.E.I.)
CDG 1 (control of eelgrass by 2,4-D)
CSG 52 (antifouling boat coatings)
53 (Maritimes wood borers)
T 3 (Oozy Creek, P.E.I. biotic survey)
21 (shipworm *Teredo* species control)
76 (Ostrea L., N.S., pre-fertilization benthic survey)
S 1210 (butoxyethanol ester of 2,4-D)
A 88 (antifouling coating for boats)
109 (eelgrass control with 2,4-D)
114 (protection from marine borers)

Thomson, John Arthur Collingwood
T 40 (multiple discriminant analysis program)
45 (extended tables of the transformation $\varphi = 2 \arcsin \sqrt{X}$)
50 (surface transport charts N Pac. Ocean, 1946–49)
51 (surface transport charts N Pac. Ocean, 1963–66)
52 (surface transport charts N Pac. Ocean, 1967)
63 (surface transport charts N Pac. Ocean, 1950–52)
64 (surface transport charts N Pac. Ocean, 1953–55)
65 (surface transport charts N Pac. Ocean, 1956–58)
66 (surface transport charts N Pac. Ocean, 1959–62)

Threadfish (*Nemichthys avocetta*)
T 11 (in experimental B.C. midwater trawling)

Thunnus alalunga (*see* Albacore)

Thunnus albacares (*see* Tuna, yellowfin)

Thunnus obesus (*see* Tuna, bigeye)

Thunnus thynnus (*see* Tuna, bluefin)

Thymallus arcticus (*see* Grayling, arctic)

Abbreviations: J — Journal; B — Bulletin; AR — Annual Report; R — Review; *Circular series*: CDG — Dartmouth; CHN — Halifax; CJG — St. John's; CNG, CNS — Nanaimo; CSG — St. Andrews; CVG — Vancouver; T — Technical Reports; MSP — Miscellaneous Special Publications; S — Studies; A — Interpretive Articles.

Thyroid
J 25(8): 1651 (re iodide in fish plasma proteins)

Thysanoëssa spinifera (a euphausid)
J 25(7): 1311 (pressure effect on respiration of vertically migrating)

Tibbo, Simeon Noel
J 25(5): 903 (swordfish feeding habits)
(5): 1075 (*Dasyatis violacea* in NW Atl.)
T 57 (Bay of Fundy herring length & age distribution)
A 92 (abnormal water temperatures affect herring fisheries)
94 (Canadian Atl. herring fishery)

Tides (*see also* Oceanography)
J 25(6): 1097 (natural oscillations in Bay of Fundy)

Tigerfish (*Therapon jarbua*)
J 25(1): 197 (microorganisms isolated from diseased)

Tilapia species
J 25(1): 197 (microorganisms isolated from diseased *T. mossambica*)
(12): 2715 (muscle creatine kinase polymorphism and localization in several species)

Tin compounds
CSG 52 (in antifouling coatings for boats)
53 (for protection against wood borers)
T 21 (for protection against shipworms)
A 88 (same as CSG 52 above)
114 (same as CSG 53 above)

Tinca tinca (*see* Tench)

Titanium compounds
J 25(11): 2327 (in St. Lawrence R. estuary glacial marine sediments)

Toadfish, oyster (*Opsanus tau*)
J 25(8): 1739 (spinal ganglia position re taxonomy)

Tocher, Carol Ann Shipton
J 25(8): 1603 (phytoplankter fatty acids)

Todd, Wilbert Remington
J 25(3): 611 (juvenile salmonid skin pallor by guanidine compounds)

Tomcod, Pacific (*Microgadus proximus*)
J 25(12): 2665 (associations with other Oregon coast fishes)
T 7, 22, 30, 56, 62, 81 (in experimental or commercial B.C. trawling)
A 91 (observed in B.C. landings of fish for mink feed)

Tomlinson, Neil
J 25(3): 603 (addendum: trout catecholamine & carbohydrate concentrations)

Tooth (*see* Teeth)

Tope (*Galeorhinus galeus*)
J 25(12): 2711 (muscle creatine kinase localization)

Topography (*see also* Hydrography)
J 25(1): 33 (of SW B.C. streams)
(1): 81 (of 3 SW B.C. lakes re trout mortality)
(6): 1181 (upper Great Lakes re benthic environment subdivisions)

Topp, Robert W.
J 25(6): 1299 (winter flounder fecundity)

Townsley, Philip MacNair
J 25(5): 853 (marine borer caecum glucose metabolism)

Toxicants; Toxicity (*see also* Herbicide; Insecticides; Pesticides; Pollution; Shellfish occasional toxicity)
CSG 52 (for combating fouling on boats)
53 (for combating wood borers)
T 21 (for combating shipworms)
A 88 (same as CSG 52 above)
114 (same as CSG 53 above)

Tracer elements (radioactive isotopes) (*see* Irradiation; Isotopes; Radiation) (*Note*: Data on ^{14}C not indexed separately because of its frequent use; *see* Biosynthesis, etc.)

Trachinotus ovatus (*see* Panpano)

Trachurus symmetricus (*see* Mackereljack)

Transaminases (*see* Enzymes)

Transferrin (*see* Serology)

Transplantation
J 25(12): 2633 (differences resulting from barnacle)
B 165 : 19 (carp into Canadian waters)
CJG 14 : 32; 15: 24 (pink salmon eggs from Pac. coast to Nfld.)
T 44 (progress report on Atl. lobsters in Fatty Basin, B.C.)
A 93 (Atl. lobsters to B.C. coast)
106 (*Oncorhynchus* salmon species to Great Lakes, Hudson Bay, & Nfld.)
108 : 12; 113 (success of pink salmon eggs transplants to Nfld.)

Transport, mass (of waters) (*see also* Currents; Oceanography)
T 50, 51, 52, 63, 64, 65, 66 (surface transport charts for NE Pac. Ocean, 1946–67)
53 (transport computations for N Pac. Ocean, 1967)

71, 72 (transport computations for Norwegian Sea, 1950–60)

Transportation of fishery products (*see also* Handling; Pumps; Sea water, refrigerated)
B 166 : 40 (eels in E Canada)

Traps
J 25(4): 733 (condition of trap-caught Atl. cod re quality of frozen)
B 166 : 7 (for commercial eel fishery)
T 38 (estuarine net counting fence for Atl. salmon)
84 (Atl. salmon & brown trout captured & marked at fence in T 38)
S 1257 (estuarine net counting fence for Atl. salmon)

Trawl; Trawling (*see also* International Commission for the Northwest Atlantic Fisheries)
J 25(3): 457 (B.C. coast midwater trawl catches re sound-scattering layers)
(3): 589 (Pac. herring schools behaviour in response to midwater trawl)
B 163 (instrumentation for study of otter trawls)
CNG 85 (semiballoon type for B.C. shrimp exploration)
T 7, 56 (catch & effort statistics of B.C. commercial, 1966, 1967)
11 (midwater: exploratory off Queen Charlotte Is.)
12, 23 (catch statistics for commercial B.C. & U.S. commercial for Pac. cod)
13 (types of B.C. trawlers & gear)
16 (experimental Pac. ocean perch, 1966)
18, 61 (in B.C. shrimp surveys)
19, 89 (summary report of B.C. experimental, 1966, 1967)
22, 81 (experimental groundfish, off W coast Vancouver Is., 1967, 1968)
30, 46, 62 (experimental groundfish, off Queen Charlotte Is., 1963–66, 1967, 1968)
A 104 (based on CNG 85 above)
108 : 18 (ICNAF studies of otter trawl action in catching Atl. cod)

Trefethen, Parker Scott
J 25(5): 867 (olfaction/vision in spawning site choice)

Tremaine, Jack Harold
S 1253 (virus structure & subunit amino acid composition)

Trematoda
T 48 (parasitic to lampreys)

Tresus capax (*see* Clam, horse)

Tresus nuttalli (*see* Clam (a Pacific))

Trevithick, J. R.
S 1245 (protamin biosynthesis)

Triaenophorus crassus; *T. nodulosus* (*see* Tapeworm)

Triggerfish (*Teuthis vermiculatus*)
J 25(1): 197 (microorganisms isolated from diseased)

Trigla gurnardis (*see* Gurnet)

Triglycerides (*see also* Acids, fatty; Lipids; Oils and fats)
J 25(8): 1561 (of jellyfish & turtle)
(10): 2083 (fatty acids distribution in Atl. cod flesh)
S 1203 (positional distribution of monoenoic fatty acids in animal)
1226 (positional distribution of fatty acids in aquatic animal depot fat)
1233 (marine fatty acids incorporation into mink & rat adipose tissue & liver fats)

Trimethylamine
J 25(5): 921 (nonbacterial production frozen Atl. cod & scallop muscle)
(8): 1753; (10): 2071 (suppression by preservatives)

Tropical marine fishes (*see* Fishes, tropical)

Trout (a European) (*Salmo fario*)
J 25(12): 2711 (muscle creatine kinase localization)

Trout, brook (*Salvelinus fontinalis*) (speckled trout)
J 25(1): 81 (limnology re mortality in 3 SW B.C. lakes)
(1): 189 (DDT residues & metabolites in)
(2): 209 (effect of ponding on catches in Ellerslie Brook, P.E.I.)
(2): 423 (infection by *Norcardia asteroides* bacteria)
(3): 579 (dissolved O_2 fluctuations effect on growth)
(5): 863 (cornea ultrastructure)
(7): 1323 (lactate dehydrogenase comparison with lake & rainbow trouts, also with albino brook trout & brook–brown hybrids)
(7): 1521 (infection by *Aeromonas*)
(9): 1787 (reproduction after DDT insecticide ingestion)
(10): 2011 (lake fertilization & predator control to increase yield of)
(11): 2443 (growth & stress resistance when fed DDT)

(12): 2643 (experimental plantings of furunculosis-infected stock)
(12): 2677 (lateral line response affected by DDT)
S 1226 (fatty acids positional distribution in fat triglycerides)

Trout, brown (*Salmo trutta*)
J 25(4): 813 (sexual dimorphism in anal fin of *S. t. trutta*, *S. t. labrax*, *S. t. macrostigma*)
(5): 863 (cornea ultrastructure)
(6): 1285 (light influence on activity)
(7): 1323 (lactate dehydrogenase in hybrid with brook trout)
(12): 2527 (world distribution)
T 84 (numbers captured & marked at Little Codroy R. (Nfld.) counting fence)

Trout, cutthroat (*Salmo clarki clarki*) (*see also* Trout, Lahontan cutthroat)
J 25(1): 33 (vs. steelhead trout juvenile distribution in SW B.C. streams)
B 162 : 243 (predator on young sockeye salmon)

Trout, Dolly Varden (*see* Dolly Varden)

Trout, grey (*see* Trout, lake)

Trout, Lahontan cutthroat (*Salmo clarki henshawi*)
J 25(11): 2519 (marking by high-frequency electric sparks)

Trout, lake (*Salvelinus* (*Cristivomer*) *namaycush*) (gray trout)
J 25(4): 667 (re Great Lakes species succession & exploitation)
(7): 1323 (lactate dehydrogenase comparison with rainbow & brook trouts)
(7): 1377 (rehabilitation in Apostle Is. region of L. Superior)
(7): 1501 (F) (range extensions in E Canadian arctic marine or saline waters)
(7): 1521 (infection by *Aeromonas*)
(11): 2257 (survival of marked vs. tagged)
T 33 (Great Slave L. fishery)

Trout, Lake Garda (*Salmo carpio*)
J 25(4): 813 (anal fin re sexual dimorphism)

Trout, Ohrid (*Salmo letnica*)
J 25(4): 813 (sexual dimorphism in anal fin)

Trout, rainbow (*Salmo gairdneri*) (*see also* Trout, steelhead)
J 25(1): 25 (M.S. 222 anesthetic excretion in urine)
(1): 71 (fluorimetric method for blood plasma cortisol)
(1): 81 (limnology re mortality in 3 SW B.C. lakes)
(1): 173 (hematological correlations)
(2): 383 (infectious pancreatic necrosis; selection of virus-free stock)
(3): 591 (growth effect on ^{65}Zn retention time)
(3): 603 (adrenaline concentrations in, re physical disturbance of)
(3): 611 (guanidine compounds effect on skin pigment of young)
(5): 863 (cornea ultrastructure)
(7): 1323 (lactate dehydrogenase comparison with brook & lake trouts)
(7): 1465 (metopirone effect on pituitary–interrenal function)
(7): 1521 (infection by *Aeromonas*)
(8): 1539 (postmortem glycogen & starch degradation in muscle)
(8): 1555 (starvation effects on blood plasma & muscle tissue)
(8): 1651 (plasma protein-bound inorganic iodide)
(8): 1689 (respiratory quotient)
(9): 1983 (thermal stress physiological interaction among fingerlings)
(10): 2011 (lake fertilization & predator control to increase yield of)
(10): 2157 (dissolution of muscle homogenates by lysolecithin)
(10): 2233 (fluorescent pigment tattoo marking of fingerlings)
(11): 2519 (marking by high-frequency electric sparks)
S 1252 (avoidance reactions to zinc sulphate solutions)
1258 (proteinase of proteolytic pseudomonad from skin lesions)

Trout, Sevan (*Salmo ischchan*)
J 25(4): 813 (sexual dimorphism in anal fin)

Trout, speckled (*see* Trout, brook)

Trout, steelhead (*Salmo gairdneri*) (*see also* Trout, rainbow)
J 25(1): 33 (vs. cutthroat trout juvenile distribution in SW B.C. streams)
(4): 690 (planting in L. Michigan tributaries)
(5): 1085 (feed habits in NE Pac. Ocean)
(7): 1453 (station permanence of juvenile)
T 24 (enumeration & sampling data, Babine R. counting fence, 1961–66)
S 1245 (protamine biosynthesis during spermatogenesis)
A 86 (INPFC oceanic research results, 1966)

Trout, "tiger" (brook × brown trout hybrid)
J 25(7): 1323 (muscle lactate dehydrogenase electrophoretic pattern)

Trout-perch (*Percopsis omiscomaycus*)
J 25(2): 255 (population estimation by stain marking)

Truscott, Beryl
J 25(2): 363 (Atl. salmon sperm subzero preservation)
(2): 431 (teleost biosynthesis)
S 1205 (1α-hydroxycorticosterone activity)
1244 (steroid 1α-hydroxylation in elasmobranchs)

Tsuyuki, Hiroshi
J 25(7): 1317 (hybrid fish protein)
(11): 2477 (protein electropherograms re rockfish systematics)
S 1204 (scombroid fishes serum transferrin polymorphism)

Tubesnout (*Aulorhynchus flavidus*)
T 62 (in experimental B.C. groundfish trawling)

Tuberculosis
B 162 : 92 (of sockeye salmon)

Tullibee (*Coregonus artedi(i)*) (*see* Herring, lake; Tullibee)
J 25(1): 169 (pesticide residues in oils & meals)
A 85 (nutrient composition of meal as poultry feed)

Tumor
T 62 (on Pac. cod gill cavity)

Tuna, bigeye (*Thunnus obesus*)
A 108 (1966 Canadian ICNAF studies: weights caught by sports fishermen)

Tuna, bluefin (*Thunnus thynnus*)
S 1204 (population units study by serum transferrin polymorphism)
A 90, 103 (fishery trend along N America Pac. coast)
108 (1966 Canadian ICNAF studies: weight of tagged; weights caught by sports fishermen)

Tuna, skipjack (*Euthynnus pelamis*) (*Katsuwonus pelamis*)
S 1204 (population units study by serum transferrin polymorphism)
A 90, 103 (fishery trend along N America Pac. coast)

Tuna, yellowfin (*Thunnus albacares*)
S 1204 (population units study by serum transferrin polymorphism)
A 90, 103 (fishery trend along N America Pac. coast)
108 (1966 Canadian ICNAF studies: weights caught by sports fishermen)

Tunicata
T 55 : 139 (identification of B.C.)

Tunicate (species)
J 25(2): 267 (occurrence & retention of thetin derivative from feed)

Turbellaria
J 25(11): 2521 (*Urastoma cyprinae* association with Atl. oyster)
T 25, 35, 59, 60, 73 (in Strait of Georgia benthos biomass)
43 (on Irish moss)

Turbidity (*see also* Sediments)
J 25(9): 2001 (F) (of habitat re walleye & sauger retinal structure)
B 167 : 259 (determination in sea water)

Turbot (Atlantic) (*see* Halibut, Greenland)

Turbot (Pacific) (*see* Flounder, arrowtooth)

Turner, Christopher Edward
J 25(9): 1993 (3rd-year pink salmon)

Turtle, leatherback (*Dermochelys coriacea coriacea*)
J 25(8): 1561 (influence of jellyfish feed on lipid fatty acids)
S 1226 (fatty acids positional distribution in dermal fat triglycerides)

Turtle, painted (*Chrysemys picta*)
J 25(8): 1651 (plasma protein-bound inorganic iodide)

Tusk
A 110 (very old walrus tusk recovered from sea off N.S.)

U

Ultrasonic effects (*see* Sound, ultrasonic)

Umbra limi (*see* Mudminnow, central)

Ungava, Que.
J 25(4): 657 (age & growth of round whitefish)

Union of Soviet Socialistic Republics (USSR)
A 90, 103 (extension of fisheries into NE Pac.)

Unloading
T 69 (fish from fishing vessels by mechanical means)

Urastoma cyprinae (*see* Worm, oyster gill)

Urea
J 25(12): 2549 (interrenalectomy effect on skate blood level of)
S 1198 (re *Hemiselmis virescens* phototrophic growth)

Uric acid
S 1231 (uricolytic enzymes in Atl. cod sperm)

Urophycis (species) (*see* Hake (Atlantic))

Urophycis tenuis (*see* Hake, white)

USSR (*see* Union of Soviet Socialistic Republics)

V

Vanadium compounds
J 25(4): 639 (catalyzing marine flesh oxidative rancidity)

Vancouver Island, B.C. (*see also* Fisheries; Oceanography, B.C. coast; Trawl)
CNG 86 (1968 coastal herring spawn deposition)

Vanstone, William Edward
J 25(11): 2403 (Pac. salmon metamorphosis)

Van Vliet, William Hauk
J 25(12): 2733 (first records of sculpins from Ottawa Valley)

Vas deferens (*see* Testes)

Vegetables
S 1253 (subunit amino acid composition re structure of viruses)

Velsen, Frank Peter John
J 25(3): 585 (fish egg incubator)

Venerupis japonica (*see* Clam, Manila)

Venno, Paul Maurice William
J 25(6): 1169 (sampling larval herring with buoyed & anchored nets)

Venom
J 25(10): 2157 (snake: effect on solubilization of fish muscle homogenate)

Venus mercenaria (*see* Quahaug, bay)

Vertebrae
S 1255 (number in NW Atl. capelin)

Vessels (*see* Boats)

Viability (*see* Eggs; Reproduction; Sperm)

Viperfish, fanged (*Chauliodus macouni*)
J 25(3): 457 (in N B.C. coast midwater trawl catches)
T 11, 81 (in experimental B.C. trawling)

Virus
J 25(2): 383 (pancreatic necrosis in young trout; virus-free stock)
S 1253 (structure of plant viruses re their subunit amino acid composition)

Viscera
J 25(9): 1797 (dieldrin in fat of goldfish, after aldrin ingestion)

Vision (*see also* Eye; Light, reactions to)
J 25(5): 867 (role in chinook salmon choosing spawning site)

Vitamin B group
J 25(1): 151 (folic acid deficiency effect on coho salmon blood)
B 167 : 159, 165, 169 (B_{12}, biotin, & B_1 determination in sea water)
A 85 (in freshwater fishmeals)

Vladykov, Vadim Dmitrovich
J 25(4): 813 (brown trout anal fin sexual dimorphism)

Volsella demissa (*see* Mussel, ribbed)

Volsella modiolus (*see* Mussel, horse)

W

Waldichuk, Michael
A 81 (water pollution detection & measurement — chemical analysis)

Waldron, Kenneth David
J 25(4): 801 (*Sebastodes pinniger* early larvae)

Wallen, Donald George
J 25(10): 2219 (C^{14} activity on storage)

Walleye (*Stizostedion vitreum vitreum*) (yellow pickerel)
J 25(4): 667 (re Great Lakes species succession & exploitation)
(7): 1347 (dynamics & exploitation in Nipigon Bay region, Ont.)
(7): 1505 (wet vs. dry weight determination of stomach contents)
(8): 1651 (plasma protein-bound inorganic iodide)
(9): 2001 (F) (retinal structure re habitat turbidity)

Walrus, Atlantic (*Odobenus rosmarus rosmarus*)
A 110 (very old tusk dragged from sea off N.S.)

Ward, Fredrick James
J 25(7): 1505 (measuring walleye stomach contents by wet weight)
(11): 2505 (^{14}C in *Daphnia pulex*)

Waste-water (*see* Pollution; Stickwater)

Waters, natural (*see also* Limnology; Oceanography)
J 25(1): 33 (*p*H, dissolved solids, & topography of SW B.C. streams)
(1): 81 (characteristics of 3 SW B.C. eutrophic lakes)

(8): 1591 (American eel rheotaxis to different stream waters)
(10): 2037 (characteristics of a hotspring stream)
B 167 (practical handbook of seawater analysis)

Watson, Jeffrey
J 25(8): 1729 (oxygen consumption of spider crab & American lobster)

Weber, Douglas Duane
J 25(3): 473 (salmon blood lactate after exercise)

Weight (*see also* Growth; Length; Size)
J 25(4): 657 (re age & length of Ungava round whitefish)
(4): 730 (as fish growth-determining factor)
(11): 2403 (re morphology of coho salmon parr–smolt transformation)
(12): 2743 (estimating mean weight from length statistics)
T 74 (dressed, vs. fork length, of sablefish)
S 1206 (of salmon from Labrador Sea & off W Greenland)

Weirs
B 166 : 29 (for catching eels commercially)

Weis, Judith S.
J 25(8): 1739 (spinal ganglia position in taxonomy)

Welsh, Linda
J 25(6): 1133 (lake fishes feeding & consumption)

Westrheim, Sigurd Jergen
J 25(11): 2477 (protein electropherograms re rockfish systematics)
(11): 2509 (first records of 3 rockfish species off B.C.)
T 16 (N Pac. ocean perch)
22 (*G. B. Reed* groundfish cruise 67-1)
30 (*G. B. Reed* groundfish reports 1963–66)
46 (*G. B. Reed* groundfish cruise 67-2)
81 (*G. B. Reed* groundfish cruise 68-2)

Whale, blue (*Sibbaldus musculus*) (*Balaenoptera musculus*)
A 107 (1966–67 marking of, in N Atl.)

Whale, Cuvier's beaked (*Ziphius cavirostris*)
S 1240 (NE Pac. stranding distribution & seasonality)

Whale, fin (*Balaenoptera physalus*)
S 1193 (pristanic & phytanic fatty acids of blubber oil)
1203 (positional distribution of monoenoic fatty acids in milk triglycerides)
1227 (fatty acid composition of milk lipids)
1228 (isoprenoid fatty acids of blubber, commercial, & milk fats, re feed)
A 107 (1964–67 catches off E Canada; 1966–67 marking research)

Whale, humpback (*Megaptera novaeangliae*)
A 107 (1966–67 marking of, in N Atl.)

Whale, killer (Atlantic) (*Grampus orca*)
A 107 (1966–67 marking of, in N Atl.)

Whale, minke (*Balaenoptera acutorostrata*)
A 107 (1966–67 marking of, in N Atl.)

Whale, pigmy sperm (*Kogia simus*)
J 25(12): 2561 (feeding habits from fish otoliths in stomach)

Whale, pilot (*Globicephala melaena*) (pothead whale)
A 107 (1966–67 marking of, in N Atl.)

Whale, pothead (*see* Whale, pilot)

Whale, right (*Eubalaena glacialis*)
A 107 (1966–67 marking of, in N Atl.)

Whale, sei (*Balaenoptera borealis*)
S 1226 (fatty acids positional distribution in blubber triglycerides)
A 107 (1966–67 marking of, in N Atl.)

Whale, sperm (*Physeter catodon*)
A 107 (1966–67 marking of, in N Atl.)

Whelk, rough (*Buccinum undatum*)
S 1255 (experimentally induced accumulation of paralytic shellfish poison)

White, G. N.
T 76 (Ostrea L., N.S., pre-fertilization benthic survey)

White, Harley Clifford
J 25(11): 2439 (Atl. salmon scales re spawning)

Whitefish (white-fleshed commercial marine species)
A 85 (nutrient values of meal as poultry feed)

Whitefish, lake (*Coregonus clupeaformis*)
J 25(3): 605 (ultrasonic effects as test for fillet quality)
(4): 667 (re Great Lakes species succession & exploitation)
(8): 1651 (plasma protein-bound inorganic iodide)

Abbreviations: J — Journal; B — Bulletin; AR — Annual Report; R — Review; *Circular series*: CDG — Dartmouth; CHN — Halifax; CJG — St. John's; CNG, CNS — Nanaimo; CSG — St. Andrews; CVG — Vancouver; T — Technical Reports; MSP — Miscellaneous Special Publications; S — Studies; A — Interpretive Articles.

(8): 1667 (cytotaxonomic relation to other Great Lakes coregonids)
(10): 2091 (growth & reproduction in Lac la Ronge, Sask.)
(10): 2111 (scales annulus formation in artificially reared)
B 162 : 234 (as food competitor of young sockeye salmon)
T 33 (Great Slave L. fishery)

Whitefish, round (*Prosopium cylindraceum*)
J 25(4): 657 (age & growth, in Ungava)
(8): 1667 (cytotaxonomic relation to other Great Lakes coregonids)

Whiting (*see* Pollock, walleye)

Whitworth, Walter Richard
J 25(3): 579 (dissolved oxygen on brook trout growth)

Wickett, William Percy
T 50 (surface transport charts N Pac. Ocean, 1946–49)
51 (surface transport charts N Pac. Ocean, 1963–66)
52 (surface transport charts N Pac. Ocean, 1967)
53 (transport computations N Pac. Ocean, 1967)
63 (surface transport charts N Pac. Ocean, 1950–52)
64 (surface transport charts N Pac. Ocean, 1953–55)
65 (surface transport charts N Pac. Ocean, 1956–58)
66 (surface transport charts N Pac. Ocean, 1959–62)
71 (transport computations for the Norwegian Sea, 1950–54)
72 (transport computations for the Norwegian Sea, 1955–60)

Wilder, Donald George
A 76 (Canada's lobster fishery)

Wiles, Michael
J 25(12): 2749 (harbour seal bounty re Atl. cod codworm infestations)

Wilimovsky, Norman Joseph
T 34 (N Pac. Ocean systematics of 6 demersal fishes)

Wilkins, Noël Patrick
J 25(12): 2651 (Atl. salmon multiple haemoglobins)

Willford, Wayne Allan
J 25(1): 25 (rainbow trout M.S. 222 excretion)

Wilson, Kerry Alexander
T 48 (checklist of parasites of lampreys)

Wind
T 85 (effect on free-floating current followers)

Wiseman, Phyllis Maxwell
S 1239 (red algae sterols)

Wissing, Thomas Edward
J 25(11): 2515 (invertebrates calorific values)

Witch (*see* Flounder, witch)

Withler, Frederick Curtis
J 25(12): 2695 (sockeye & pink salmon chilled ova & sperm)

Wolf, Ken
J 25(2): 383 (infectious pancreatic necrosis virus-free trout selection)

Wolf-eel (*Anarrchichthys ocellatus*)
T 11, 46, 81 (in B.C. experimental trawling)

Wolffish, Atlantic (*Anarhichas lupus*)
CJG 14 (Nfld. landings, 1966)
15 (Nfld. landings, 1952–67)
T 80 (stocks, Gulf of St. Lawrence & N.S. Banks)

Wolotira, Robert John, Jr.
J 25(5): 1077 (*Isopsetta isolepis* in Bering Sea)

Wong, Joseph
CVG 38 (waste-water clarification)

Wood borers (*see Bankia; Limnoria;* Shipworm)

Worlund, Donald Duane
J 25(9): 1971 (ageing chinook salmon from scales)

Worm, oyster gill (*Urastoma cyprinae*)
J 25(11): 2521 (association with Atl. oyster)

Worms (*see* Acanthocephala; Annelida; Cestoda; Chaetognatha; Nematoda; Trematoda; Tubellaria; *also* Arrow-worm; Codworm; Earthworms; Shipworm; Tapeworms)

X

Xanthophyceae
J 25(8): 1603 (fatty acids)

Xeneretmus latifrons (*see* Poacher, blacktip)

Xeneretmus triacanthus (*see* Poacher, blue spotted)

Xiphias gladius (*see* Swordfish)

Y

Yamazaki, Fumio
J 25(7): 1497 (salmon pituitary "prolactin")
S 1249 (spermiation bioassay for gonadotropin)

Year-class (*see* Age)

Yellowtail (*Seriola dorsalis*) (*see also* Flounder, yellowtail)
A 90, 103 (fishery trend along N America Pac. coast)

Yesaki, Mitsuo
J 25(5): 1077 (*Isopsetta isolepis* in Bering Sea)

Yield (*see also* Angling; Catches)
J 25(10): 2011 (fertilizing lake to increase trout)
(12): 2589 (Fraser R. white sturgeon)

Z

Zaprora silenus (*see* Prowfish)

Zebrafish (*Brachydanio rerio*)
J 25(8): 1739 (spinal ganglia position re taxonomy)

Zinc compounds (*see also* Mineral content)
J 25(3): 591 (growth effect of trout on ^{65}Zn retention)
(4): 639 (catalyzing fatty fish flesh oxidative rancidity)
(11): 2461 (distribution of natural ^{65}Zn in small Crustacea)
(12): 2691 (^{65}Zn metabolism in freshwater mussel)
S 1196 (re mining pollution effects on spawning Atl. salmon)
1252 (rainbow trout avoidance reactions to sulphate solutions)
A 85 (in freshwater fishmeal)
111 (NTA sequestering agent to combat pollution from)

Ziphius cavirostris (*see* Whale, Cuvier's beaked)

Zooplankton (*see also* Feed; Plankton)
J 25(5): 943 (*Anonyx* species of N America Atl. & arctic coasts)
(5): 1071 (*Meganyctiphanes norvegica* larvae off W Greenland)
(8): 1549 (associated with Gulf of Maine red water bloom)
CNG 84 (description, classification, & key to NE Pac. marine)
T 37 (net selection for coastal waters)
55 (manual & key for identification of B.C. marine)
77 (biomass re primary productivity, St. Margaret's Bay, N.S.)

Zostera marina (*see* Eelgrass)

Abbreviations: J — Journal; B — Bulletin; AR — Annual Report; R — Review; *Circular series*: CDG — Dartmouth; CHN — Halifax; CJG — St. John's; CNG, CNS — Nanaimo; CSG — St. Andrews; CVG — Vancouver; T — Technical Reports; MSP — Miscellaneous Special Publications; S — Studies; A — Interpretive Articles.

LISTS OF PUBLICATIONS

JOURNAL OF THE FISHERIES RESEARCH BOARD OF CANADA

(A complete list of the contents for the 1968 Volume 25 is included at the back of this issue for binding purposes.)

BULLETINS OF THE FISHERIES RESEARCH BOARD OF CANADA

162. FOERSTER, R. E. The sockeye salmon, *Oncorhynchus nerka*. xv + 422 p.

163. CARROTHERS, P. J. G. Instrumentation for the engineering study of otter trawls. vii + 45 p.

164. CARTER, NEAL M. Index and list of titles, Fisheries Research Board of Canada and associated publications, 1900–1964. xviii + 649 p.

165. MCCRIMMON, HUGH R. Carp in Canada. ix + 93 p.

166. EALES, J. GEOFFREY. The eel fisheries of eastern Canada. x + 79 p.

167. STRICKLAND, J. D. H., AND T. R. PARSONS. A practical handbook of seawater analysis. xi + 311 p.

---

131. MEDCOF, J. C. L'ostréiculture dans les provinces Maritimes. xi + 178 p. [English edition published in 1961.]

---

119. RICKER, W. E. Handbook of computations for biological statistics of fish populations. 300 p. [Reprinted with corrections 1963; reprinted without revision 1968.]

CIRCULARS OF THE FISHERIES RESEARCH BOARD OF CANADA

Marine Ecology Laboratory, Bedford Institute, Dartmouth, N.S.

1. THOMAS, M. L. H. Control of eelgrass using 2,4-D in oyster-growing areas. 4 p.

Halifax Laboratory, Halifax, N.S.

32. JANGAARD, P. M., AND A. SAITO. Japanese frozen minced fish (fish paste) products. 2 p.

33. JANGAARD, P. M. Suggestions for handling shrimp caught off the Atlantic coast of Canada. 2 p.

34. JANGAARD, P. M. The Maine shrimp industry, March, 1968. 3 p.

Biological Station, St. John's, Nfld.

14. FLEMING, A. M. [ed.] [various authors]. Fishery investigations and groundfish landings in Newfoundland, 1966. 47 p.

15. FLEMING, A. M. [ed.] [various authors]. Fishery investigations and groundfish landings in Newfoundland, 1967. 44 p.

Biological Station, Nanaimo, B.C.

84. LEBRASSEUR, R., AND J. FULTON. A guide to zooplankton of the northeastern Pacific Ocean. 34 p. [1967]

85. SMITH, M. S., AND T. H. BUTLER. Shrimp exploration on the British Columbia coast 1967. 41 p.

86. OUTRAM, D. N. The 1968 herring spawn deposition in the coastal waters of British Columbia. 9 p.

Biological Station, Nanaimo, B.C.
(Statistical Series)

26. BILTON, H. T., E. A. R. BALL, AND D. W. JENKINSON. Age, size and sex composition of British Columbia chum salmon catches from 1957 to 1963. 2 p. + 192 tables. [1967]

Biological Station, St. Andrews, N.B.

52. THOMAS, M. L. H. Anti-fouling coatings for boats. 3 p.

53. THOMAS, M. L. H. Test new treatment to protect wood from marine borers. 5 p.

Vancouver Laboratory, Vancouver, B.C.

38. CLAGGETT, F. G., AND J. WONG. Salmon canning waste-water clarification. Part 1. Flotation by total flow pressurization. 9 p.

39. CLAGGETT, F. G. Fish meal pilot plant for research. 3 p.

40. CLAGGETT, F. G. The use and application of antioxidants for control of spontaneous heating in Canadian herring meal. 14 p.

ANNUAL REPORT

Annual Report Fisheries Research Board of Canada 1967. 36 p. (combined English and French).

REVIEW

Review of the Fisheries Research Board of Canada 1965/1966. 148 p.

MISCELLANEOUS SPECIAL PUBLICATIONS

10. The Fisheries Research Board of Canada — What it is and what it does. 1968. 18 p.

11. The Fisheries Research Board of Canada and its place in Canada's scientific development 1968–1978. 176 p.

TECHNICAL REPORTS OF THE FISHERIES RESEARCH BOARD OF CANADA

1. BUTLER, T. H. A bibliography of the Dungeness crab, *Cancer magister* Dana. 12 p. [1967]

2. BERNARD F. Prodrome for a distributional check-list and bibliography of the recent marine Mollusca of the west coast of Canada. 261 p. [1967]

3. THOMAS, M. L. H., AND M. J. PARKS. A biotic survey of Oozy Creek, a small arm of Bideford River, Prince Edward Island. 15 p. + 4 tables + 3 fig. [1967]

4. FORSYTHE, M. G. Analysis of the 1965 smolt run in the northwest Miramichi River, New Brunswick. 73 p. [1967]

5. STODDARD, JUDITH H. Studies of the condition (fatness) of herring. 7 p. + 4 tables + 5 fig. [1967]

6. ELSON, P. F., AND J. R. MACDONALD. Methods for evaluating damage, by New Brunswick forest spraying programs, to salmon fisheries. 33 p. + 6 tables + 6 fig. [1967]

7. HOLMBERG, DEANNA. Catch and effort statistics of the British Columbia trawl fishery in 1966. 87 p. [1967]

8. [Not yet published and not included in this index.]

9. SYMONS, P. E. K. Retention of Pletcher grow-thru tags applied to young salmon. 6 p. + 2 fig. [1967]

10. COBURN, A. S., AND H. T. BILTON. The age, size and sex composition of sockeye in the escapements to Schulbuckhand and Williams Creeks, Lakelse Lake, B.C. in 1965 and 1966. 19 p. [1967]

11. TAYLOR, F. H. C. Midwater trawl catches from Queen Charlotte Sound and the open ocean adjacent to the Queen Charlotte Islands. 44 p. [1967]

12. KETCHEN, K. S., AND D. M. HOLMBERG. Catch statistics of the Canadian and United States trawl fishery for Pacific cod (*Gadus macrocephalus*), 1935–65. 23 p. [1967]

13. LIPPA, E. J. R. British Columbia trawlers and trawl gear. 47 p. [1967]

14. CLAGGETT, F. G. Clarification of waste water other than stickwater from British Columbia fishing plants. 8 p. [1967]

15. BOURNE, N. Digging efficiency trials with a hydraulic clam rake. 23 p. [1967]

16. WESTRHEIM, S. J. Catch rates, size composition, and sex ratio of Pacific ocean perch (*Sebastodes alutus*) caught in the eastern North Pacific Ocean (Vancouver Island, B.C., to southeastern Alaska) by the *G. B. Reed*, August–October 1966. 32 p. [1967]

17. PARKER, ROBERT R. Results of preliminary testing of the application of micro-magnetic tags to pink salmon fry. 21 p. [1967]

18. BUTLER, T. H. Shrimp exploration and fishing in the Gulf of Alaska and Bering Sea. 49 p. [1967]

19. FORRESTER, C. R., AND D. M. HOLMBERG. A summary report of the British Columbia trawl fishery in 1966 and some aspects of its investigation. 32 p. [1967]

20. ALLEN, K. RADWAY. Computer programmes available at St. Andrews Biological Station. 32 p. + 11 app. [1967]

21. THOMAS, M. L. H. Experiments in the control of shipworm *Teredo* sp. using bis(tri-N-butyltin) oxide. 13 p. + 1 fig. + 10 tables. [1967]

22. HARLING, W. R., D. DAVENPORT, AND S. J. WESTRHEIM. *G. B. Reed* groundfish cruise No. 67-1, February 1 to April 24, 1967. 56 p. [1967]

23. KETCHEN, K. S. Length composition of Pacific cod (*Gadus macrocephalus*) in landings by Canadian trawlers 1951–66. 27 p. [1967]

24. JORDAN, F. P. Summary of salmon enumeration and sampling data, Babine River counting fence, 1961–1966. 29 p. [1967]

25. Ellis, Derek V. Quantitative benthic investigations. I. Satellite Channel biomass summaries and major taxon rank orders, February 1965 – May 1967. 49 p. + 2 fig. [1967]

26. Blackford, B. L. Some oceanographic observations in the southern Gulf of St. Lawrence — summer, 1965. 34 p. [1967]

27. May, A. W. Biological data on cod from the summer fishery on the north shore Strait of Belle Isle. 21 p. [1967]

28. Eales, J. Geoffrey. A bibliography of the eels of the genus *Anguilla*. 171 p. [1967]

29. Allen, K. R., and J. K. Lindsey. Commercial catches of Atlantic salmon in the Maritimes area 1949–1965. 143 p. [1967]

30. Westrheim, S. J. *G. B. Reed* groundfish cruise reports, 1963–66. 288 p. [1967]

31. MacKay, K. T. An ecological study of mackerel, *Scomber scombrus* (Linnaeus), in the coastal waters of Canada. 127 p. [1967]

32. Hollister, H. J. Sea surface temperature and salinity at shore stations along the British Columbia coast during 1965. 45 p. [1967]

33. Keleher, J. J. The number of fishermen in relation to production in the Great Slave Lake winter fishery, 1957–1963. 15 p. [1967]

34. Wilimovsky, N. J., A. Peden, and J. Peppar. Systematics of six demersal fishes of the North Pacific Ocean. 95 p. [1967]

35. Ellis, Derek V. Quantitative benthic investigations. II. Satellite Channel species data February 1965 – May 1965. 7 p. + 169 tables + 2 fig. [1967]

36. Levings, Colin D. A comparison of the growth rates of the rock sole, *Lepidopsetta bilineata* Ayres, in northeast Pacific waters. 43 p. [1967]

37. LeBrasseur, R. J., C. D. McAllister, J. D. Fulton, and O. D. Kennedy. Selection of a zooplankton net for coastal observations. 13 p. [1967]

38. Murray, A. R. A counting fence of netting for Atlantic salmon in the estuary of the Little Codroy River, Newfoundland. 19 p. [1967]

39. Keleher, J. J. Description of a computer tape system for processing fisheries data. 26 p. [1967]

40. Pienaar, L. V., and J. A. Thomson. A program for multiple discriminant analysis (Fortran 1130). 32 p.

41. FORRESTER, C. R., AND D. F. ALDERDICE. Preliminary observations on embryonic development of the petrale sole (*Eopsetta jordani*). 21 p.

42. BERNARD, F. R. Studies on the biology of the naticid clam drill *Polinices lewisi* (Gould) [Gastropoda Prosobranchiata]. 41 p.

43. LILLY, GEORGE R. Some aspects of the ecology of Irish moss, *Chondrus crispus* (L.) Stack., in Newfoundland waters. 44 p.

44. GHELARDI, R. J. Progress report on the 1965 and 1966 lobster introductions at Fatty Basin, Vancouver Island, British Columbia. 40 p.

45. DRYBURGH, J. R., J. A. THOMSON, AND D. F. ALDERDICE. Extended tables of the transformation $\varphi = 2 \arcsin \sqrt{\bar{X}}$. 20 p.

46. WESTRHEIM, S. J., W. R. HARLING, AND D. DAVENPORT. *G. B. Reed* groundfish cruise No. 67-2, September 6 to October 4, 1967. 45 p.

47. STEELE, D. H., AND PIERRE BRUNEL. Collections of amphipods of the genus *Anonyx*, mainly from the Atlantic and arctic coasts of North America. 73 p.

48. RONALD, K., AND K. A. WILSON. A check list of the parasites of the order Petromyzontiformes (lampreys). 23 p.

49. HOURSTON, A. S. Age determination of herring at the Biological Station, St. John's, Newfoundland. 24 p.

50. WICKETT, W. PERCY, J. A. C. THOMSON, AND L. V. PIENAAR. Surface transport charts for the North Pacific Ocean, 1946–1949. 3 p. + 94 charts.

51. WICKETT, W. PERCY, J. A. C. THOMSON, AND L. V. PIENAAR. Surface transport charts for the North Pacific Ocean, 1963–1966. 3 p. + 86 charts.

52. WICKETT, W. PERCY, J. A. C. THOMSON, AND L. V. PIENAAR. Surface transport charts for the North Pacific Ocean, 1967. 3 p. + 24 charts.

53. WICKETT, W. PERCY. Transport computations for the North Pacific Ocean, 1967. 92 p.

54. DODIMEAD, A. J. Temperatures and salinities of the northeast Pacific Ocean during 1965 and 1966 with appendix data record of bathythermograms April–August, 1965 and 1966. 80 p.

55. FULTON, JOHN. A laboratory manual for the identification of British Columbia marine zooplankton. 141 p.

56. PREST, JANICE. Catch and effort statistics of the British Columbia trawl fishery in 1967. 85 p.

57. MESSIEH, S. N., C. D. BURNETT, AND S. N. TIBBO. Length and age distribution — Bay of Fundy herring. 64 p.

58. HOURSTON, A. S., AND R. CHAULK. Herring landings and catches in Newfoundland and their implications concerning the distribution and abundance of the stocks. 77 p.

59. ELLIS, DEREK V. Quantitative benthic investigations. III. Locality and environmental data for selected stations (mainly from Satellite Channel, Straits of Georgia and adjacent inlets), February 1965 – December 1967. viii + 10 p. + 6 fig. + 61 tables.

60. ELLIS, DEREK V. Quantitative benthic investigations. IV. Biomass summaries and major taxon rank orders for selected stations (mainly Straits of Georgia and adjacent inlets), May 1965 – December 1967. 6 p. + 2 fig. + 81 tables.

61. BUTLER, T. H., AND M. S. SMITH. Shrimp sampling and temperature data obtained during exploratory fishing off British Columbia, 1966 and 1967. 92 p.

62. LEVINGS, C. D. Report on groundfish cruise of C.G.S. *G. B. Reed* to Hecate Strait in February 1968. 41 p.

63. WICKETT, W. PERCY, J. A. C. THOMSON, AND L. V. PIENAAR. Surface transport charts for the North Pacific Ocean, 1950–1952. 3 p. + 70 charts.

64. WICKETT, W. PERCY, J. A. C. THOMSON, AND L. V. PIENAAR. Surface transport charts for the North Pacific Ocean, 1953–1955. 3 p. + 60 charts.

65. WICKETT, W. PERCY, J. A. C. THOMSON, AND L. V. PIENAAR. Surface transport charts for the North Pacific Ocean, 1956–1958. 3 p. + 72 charts.

66. WICKETT, W. PERCY, J. A. C. THOMSON, AND L. V. PIENAAR. Surface transport charts for the North Pacific Ocean, 1959–1962. 3 p. + 96 charts.

67. SINCLAIR, R. E., AND H. E. POWER. Volumetric determination of non-complexed EDTA. I. Disodium and tetrasodium salts. II. Disodium calcium salts. 6 p.

68. SINCLAIR, R. E., AND H. E. POWER. Colorimetric determination of EDTA salts on haddock, cod and flounder. I. Determination of EDTA salts on haddock, cod and flounder fillets. II. Determination of EDTA salts in drip from fillets. 11 p.

69. POWER, H. E. A study of mechanical unloading devices for fish in use on the Atlantic coast. 14 p.

70. DODIMEAD, A. J., AND R. H. HERLINVEAUX. Some oceanographic features of the waters of the central British Columbia coast. 26 p. + 107 fig.

71. WICKETT, W. PERCY. Transport computations for the Norwegian Sea, 1950–1954. 192 p.

72. WICKETT, W. PERCY. Transport computations for the Norwegian Sea, 1955–1960. 228 p.

73. ELLIS, DEREK V. Quantitative benthic investigations. V. Species data from selected stations (Straits of Georgia and adjacent inlets) May 1965 – May 1966. 7 p. + 307 tables.

74. KENNEDY, W. A., AND F. T. PLETCHER. The 1964–65 sablefish study. 24 p.

75. DODIMEAD, A. J. Oceanographic conditions in the central subarctic Pacific region, winter 1966. 10 p. + 11 fig.

76. THOMAS, M. L. H., AND G. N. WHITE. A pre-fertilization benthic survey of Ostrea Lake, N.S. 11 p. + 5 tables + 2 app. + 1 fig.

77. PLATT, TREVOR, AND BRIAN IRWIN. Primary productivity measurements in St. Margaret's Bay, 1967. 123 p.

78. KENNEDY, W. A. An octagonal pound for live fish. 5 p. + 5 fig.

79. [Not yet published and not included in this index.]

80. KOHLER, A. C. Fish stocks of the Nova Scotia Banks and Gulf of St. Lawrence. 9 p. + 16 fig.

81. HARLING, W. R., D. DAVENPORT, L. E. MCLEOD, AND S. J. WESTRHEIM. *G. B. Reed* groundfish cruise No. 68-2, April 2 to June 11, 1968. 63 p.

82. HOLLISTER, H. J. Sea surface temperature and salinity at shore stations along the British Columbia coast in 1966. 39 p.

83. PIPPY, JOHN H. C., A preliminary bibliography on parasites and diseases of Atlantic salmon (*Salmo salar*). 8 p.

84. MURRAY, A. R. Numbers of Atlantic salmon and brook trout captured and marked at the Little Codroy River, Newfoundland, counting fence and auxiliary traps, 1954–63. 135 p.

85. TERHUNE, L. D. B. Free-floating current followers. 21 p. + 6 fig.

86. [Not yet published and not included in this index.]

87. LINDSEY, J. K. Program for the analysis of non-linear response surfaces. 94 p.

88. [Not yet published and not included in this index.]

89. FORRESTER, C. R., AND J. E. PREST. A summary report of the British Columbia trawl fishery in 1967 and some aspects of its investigation. 29 p.

STUDIES OF THE FISHERIES RESEARCH BOARD OF CANADA

1192. ACKMAN, R. G., AND JOHN D. CASTELL. 1967. A generalized study of the effect of structure and other factors in open tubular gas chromatography of fatty acids on a polyester liquid phase with particular reference to monoethylenic fatty acid isomers. J. Gas Chromatog., **5**(10): 489–496.

1193. ACKMAN, R. G., AND R. P. HANSEN. 1967. The occurrence of diastereomers of phytanic and pristanic acids and their determination by gas–liquid chromatography. Lipids, **2**(5): 357–362.

1194. BRUCE, D. L., D. C. B. DUFF, AND N. J. ANTIA. 1967. The identification of two antibacterial products of the marine planktonic alga *Isochrysis galbana*. J. Gen. Microbiol., **48**: 293–298.

1195. BUTTKUS, H. 1967. The reaction of myosin with malonaldehyde. J. Food Sci., **32**(4): 432–434.

1196. SAUNDERS, RICHARD L., AND JOHN B. SPRAGUE. 1967. Effects of copper–zinc mining pollution on a spawning migration of Atlantic salmon. Water Res., **1**: 419–432.

1197. ANTIA, NAVAL J. 1967. Comparative studies on aldolase activity in marine planktonic algae, and their evolutionary significance. J. Phycol., **3**(2): 81–85.

1198. ANTIA, N. J., AND V. CHORNEY. 1968. Nature of the nitrogen compounds supporting phototrophic growth of the marine cryptomonad *Hemiselmis virescens*. J. Protozool., **15**(1): 198–201.

1199. CLARKE, A. H., D. J. STANLEY, J. C. MEDCOF, AND R. E. DRINNAN. 1967. Ancient oyster and bay scallop shells from Sable Island. Nature, **215**(5106): 1146–1148.

1200. SERGEANT, D. E. 1967. Age determination of land mammals from annuli. Z. Säugetierkunde, **32**(5): 297–300.

1201. MAY, ARTHUR W. 1967. Occurrence of ptarmigan off northern Labrador. Canadian Field-Naturalist, **81**(3): 227–228.

1202. MANSFIELD, A. W. 1966. The grey seal in eastern Canadian waters. Canadian Audubon Magazine, Nov.–Dec. Canadian Audubon Society, Toronto, Ontario. p. 161–166.

1203. BROCKERHOFF, H., AND R. G. ACKMAN. 1967. Positional distribution of isomers of monoenoic fatty acids in animal glycerolipids. J. Lipid Res., **8**: 661–666.

1204. BARRETT, IZADORE, AND H. TSUYUKI. 1967. Serum transferrin polymorphism in some scombroid fishes. Copeia, 1967(3): 551–557.

1205. IDLER, D. R., H. C. FREEMAN, AND B. TRUSCOTT. 1967. Biological activity and protein-binding of 1α-hydroxycorticosterone: an interrenal steroid in elasmobranch fish. Gen. Comp. Endocrinol., **9**(2): 207–213.

1206. TEMPLEMAN, WILFRED. 1967. Atlantic salmon from the Labrador Sea and off West Greenland, taken during *A. T. Cameron* cruise, July–August 1965. Intern. Comm. Northwest Atlantic Fish., Res. Bull. No. 4. p. 5–40.

1207. PITT, T. K. 1967. Diurnal variation in the catches of American plaice, *Hippoglossoides platessoides* Fabr., from the Grand Bank. Intern. Comm. Northwest Atlantic Fish., Res. Bull. No. 4. p. 53–58.

1208. MAY, A. W. 1967. Otolith age validation in Labrador cod. Intern. Comm. Northwest Atlantic Fish., Res. Bull No. 4. p. 116–120.

1209. MAY, A. W. 1967. Effect of offshore fishing on the inshore Labrador cod fishery. Intern. Comm. Northwest Atlantic Fish., Res. Bull. No. 4. p. 67–75.

1210. THOMAS, M. L. H., AND J. R. DUFFY. 1968. Butoxyethanol ester of 2,4-D in the control of eelgrass (*Zostera marina* L.) and its effects on oysters (*Crassostrea virginica* Gmelin) and other benthos. Proc. Northeastern Weed Control Conf., Vol. 22. p. 186–194.

1211. KOHLER, A. C. 1967. Changes in the fishery for Atlantic halibut, *Hippoglossus hippoglossus* L., in ICNAF Subareas 3 and 4, 1954–64. Intern. Comm. Northwest Atlantic Fish., Res. Bull. No. 4. p. 87–90.

1212. POWLES, P. M., AND V. S. KENNEDY. 1967. Age determination of Nova Scotia greysole, *Glyptocephalus cynoglossus* L., from otoliths. Intern. Comm. Northwest Atlantic Fish., Res. Bull. No. 4. p. 91–100.

1213. POWLES, P. M. 1967. Length–weight relationships for American plaice, witch, and yellowtail, in ICNAF Subarea 4. Intern. Comm. Northwest Atlantic Fish., Res. Bull. No. 4. p. 121–123.

1214. LI, M. F., AND CAROL FLEMMING. 1967. Hemagglutinins from oyster hemolymph. Canadian J. Zool., **45**: 1225–1234.

1215. LAUZIER, L. M. 1967. Recent trends in temperature variations in ICNAF Subarea 4. Intern. Comm. Northwest Atlantic Fish., Redbook Part IV. p. 24–32.

1216. TEMPLEMAN, WILFRED. 1967. Anomalies of sea temperature at Station 27 off Cape Spear and of air temperature at Torbay-St. John's. Intern. Comm. Northwest Atlantic Fish., Redbook Part IV. p. 69–75.

1217. ALLEN, K. R. 1967. A revised estimate of the rate of growth between Greenland and home waters of salmon from the Miramichi River, New Brunswick, Canada. Intern. Comm. Northwest Atlantic Fish., Redbook Part III. p. 66–68.

1218. ALLEN, K. R. 1967. Results of Atlantic salmon tagging in the Maritime Provinces of Canada, 1964–66. Intern. Comm. Northwest Atlantic Fish., Redbook Part III. p. 69–73.

1219. BERKELEY, C. 1967. A checklist of Polychaeta recorded from British Columbia since 1923, with references to name changes, descriptions, and synonymies. I. Errantia. Canadian J. Zool., **45**: 1049–1059.

1220. MITCHELL, EDWARD. 1967. Controversy over diphyly in pinnipeds. Systematic Zool., **16**(4): 350–351.

1221. MARCH, B. E., JACOB BIELY, AND H. L. A. TARR. 1967. The effect of fish meal supplementation of chicken breeder rations on hatchability. Poultry Sci., **46**(6): 1532–1536.

1222. ADDISON, R. F., AND R. G. ACKMAN. 1968. Flame ionization detector molar responses for methyl esters of some polyfunctional metabolic acids. J. Gas Chromatog., **6**: 135–138.

1223. STEPHENS, K., R. W. SHELDON, AND T. R. PARSONS. 1967. Seasonal variations in the availability of food for benthos in a coastal environment. Ecology, **48**(5): 852–855.

1224. GILGAN, M. W., AND D. R. IDLER. 1967. The conversion of androstenedione to testosterone by some lobster (*Homarus americanus* Milne Edwards) tissues. Gen. Comp. Endocrinol., **9**(3): 319–324.

1225. ACKMAN, R. G. 1967. The chain-length overlap problem in gas–liquid chromatography with polyester liquid phases. Lipids, **2**(6): 502–505.

1226. BROCKERHOFF, H., R. J. HOYLE, P. C. HUANG, AND CARTER LITCHFIELD. 1968. Positional distribution of fatty acids in depot triglycerides of aquatic animals. Lipids, **3**(1): 24–29.

1227. ACKMAN, R. G., C. A. EATON, AND S. N. HOOPER. 1968. Lipids of the fin whale (*Balaenoptera physalus*) from North Atlantic waters. IV. Fin whale milk. Canadian J. Biochem., **46**: 197–203.

1228. ACKMAN, R. G., AND S. N. HOOPER. 1968. Examination of isoprenoid fatty acids as distinguishing characteristics of specific marine oils with particular reference to whale oils. Comp. Biochem. Physiol., **24**: 549–565.

1229. SHIEH, H. S. 1968. Enzymatic oxidation of ^{14}C-labelled betaine by the marine microbe *Achromobacter cholinophagum*. Canadian J. Biochem., **46**: 21–23.

1230. ARO, K. V., AND M. P. SHEPARD. 1967. Salmon of the North Pacific Ocean — Part IV. Spawning populations of North Pacific salmon. 5. Pacific salmon in Canada. Intern. North Pacific Fish. Comm., Bull. No. 23. p. 225–327.

1231. MOUNIB, M. S., AND J. S. EISAN. 1968. Uricolytic enzymes in cod sperm. Canadian J. Physiol. Pharmacol., **46**: 283–284.

1232. GOLDSACK, D. E. 1968. Volume fraction of the polypeptide chain in proteins and the concentration of protein denaturants. Biopolymers, **6**: 164–165.

1233. BROCKERHOFF, H., R. J. HOYLE, AND P. C. HUANG. 1967. Incorporation of fatty acids of marine origin into triglycerides and phospholipids of mammals. Biochim. Biophys. Acta, **144**: 541–548.

1234. PLATFORD, R. F. 1968. Isopiestic measurements on the system H_2O–NaCl–Na_2SO_4 at 25°C. J. Chem. Eng. Data, **13**(1): 46–48.

1235. ALLEN, K. RADWAY. 1967. Some quick methods for estimating the effect on catch of changes in the size limit. J. Conseil, Conseil Perm. Intern. Exploration Mer, **31**(1): 111–126.

1236. MOUNIB, M. S., AND J. S. EISAN. 1968. Biosynthesis of lipids by salmon sperm from pyruvate, acetate and glyoxylate. Comp. Biochem. Physiol., **25**: 193–200.

1237. MOUNIB, M. S., AND J. S. EISAN. 1968. Carbon dioxide fixation by spermatozoa of cod. Comp. Biochem. Physiol., **25**: 703–709.

1238. ACKMAN, R. G. 1968. Prediction of retention times in the GLC of diastereoisomers of methyl-branched fatty acids. J. Chromatog., **34**: 165–173.

1239. IDLER, D. R., AKIRA SAITO, AND P. WISEMAN. 1968. Sterols in red algae (Rhodophyceae). Steroids, April. p. 465–473.

1240. MITCHELL, EDWARD. 1968. Northeast Pacific stranding distribution and seasonality of Cuvier's beaked whale *Ziphius cavirostris*. Canadian J. Zool., **46**: 265–279.

1241. SPRAGUE, J. B. 1968. Apparent DDT tolerance in an aquatic insect disproved by test. Canadian Entomol., **100**(3): 279–284.

1242. SAUNDERS, RICHARD L. 1968. An evaluation of two methods of attaching tags to Atlantic salmon smolts. Progressive Fish-Culturist, **30**(2): 104–109.

1243. BERKELEY, C. 1968. A checklist of Polychaeta recorded from British Columbia since 1923, with references to name changes, descriptions, and synonymies. II. Sedentaria. Canadian J. Zool., **46**: 557–567.

1244. TRUSCOTT, B., AND D. R. IDLER. 1968. The widespread occurrence of a corticosteroid 1α-hydroxylase in the interrenals of Elasmobranchii. J. Endocrinol., **40**: 515–526.

1245. INGLES, C. J., J. R. TREVITHICK, M. SMITH, AND G. H. DIXON. 1966. Biosynthesis of protamine during spermatogenesis in salmonid fish. Biochem. Biophys. Res. Commun., **22**(6): 627–634.

1246. BORDEN, R. KEITH, AND MICHAEL SMITH. 1966. Nucleotide synthesis. III. Preparation of nucleoside-3′,5′ cyclic phosphates in strong base. J. Org. Chem., **31**: 3247–3253.

1247. BORDEN, R. KEITH, AND MICHAEL SMITH. 1966. Nucleotide synthesis. II. Nucleotide *p*-nitrophenyl and 2,4-dinitrophenyl esters. J. Org. Chem., **31**: 3241–3246.

1248. BILINSKI, E., N. J. ANTIA, AND Y. C. LAU. 1968. Characterization of phospholipase C from a marine planktonic alga (*Monochrysis lutheri*). Biochim. Biophys. Acta, **159**: 496–502.

1249. YAMAZAKI, FUMIO, AND EDWARD M. DONALDSON. 1968. The spermiation of goldfish (*Carassius auratus*) as a bioassay for salmon (*Oncorhynchus tshawytscha*) gonadotropin. Gen. Comp. Endocrinol., **10**(3): 383–391.

1250. BROCKERHOFF, H. 1968. Substrate specificity of pancreatic lipase. Biochim. Biophys. Acta, **159**: 296–303.

1251. IDLER, D. R., AND D. A. HORNE. 1968. Recovery of microquantities of steroids from silica gel following repeated thin-layer chromatography. Steroids, **11**(6): 909–914.

1252. SPRAGUE, JOHN B. 1968. Avoidance reactions of rainbow trout to zinc sulphate solutions. Water Res., **2**: 367–372.

1253. TREMAINE, J. H., AND D. E. GOLDSACK. 1968. The structure of regular viruses in relation to their subunit amino acid composition. Virology, **35**(2): 227–237.

1254. MACLEAN, IAIN, GEOFFREY EGLINTON, K. DOURAGHI-ZADEH, R. G. ACKMAN, AND S. N. HOOPER. 1968. Correlation of stereoisomerism in present day and geologically ancient isoprenoid fatty acids. Nature, **218**(5146): 1019–1023.

1255. TEMPLEMAN, WILFRED. 1968. Review of some aspects of capelin biology in the Canadian area of the north-west Atlantic. Rappt. Proces-Verbaux Reunions Conseil Perm. Exploration Mer, **158**: 41–53.

1256. CADDY, J. F., AND R. A. CHANDLER. 1968. Accumulation of paralytic shellfish poison by the rough whelk (*Buccinum undatum* L.). Proc. Natl. Shellfish. Assoc., **58**: 46–50.

1257. MURRAY, A. R. 1968. Estuarine net counting fence for trapping Atlantic salmon. Trans. Am. Fish. Soc., **97**(3): 282–286.

1258. LI, M. F., AND CAROL JORDAN. 1968. A proteolytic pseudomonad from skin lesions of rainbow trout (*Salmo gairdnerii*). II. Some properties of the proteinase. Canadian J. Microbiol., **14**(8): 875–880.

1259. DONALDSON, E. M., AND U. H. FAGERLUND. 1968. Changes resulting from sexual maturation, in the half life (T 1/2) and volume of distribution (V) of radioactivity after injection of C^{14} (F) into salmon. Excerpta Med. Intern. Congr. Ser. 157, Item No. 348.

1260. SQUIRES, H. J. 1968. Some aspects of adaptation in decapod Crustacea in the north-west Atlantic. Proc. Symp. Crustacea, Pt. III. p. 987–995.

1261. DINGLE, J. R., J. A. HINES, AND DORIS I. FRASER. 1968. Post-mortem degradation of adenine nucleotides in muscle of the lobster, *Homarus americanus*. Food Sci., **33**(1): 100–103.

1262. NEATE, HARRY. 1968. Gear modifications for the electrofishing of underyearling coho salmon. Progressive Fish-Culturist, **30**(3): 181–182.

INTERPRETIVE ARTICLES OF THE FISHERIES RESEARCH BOARD OF CANADA

76. WILDER, D. G. 1968. A researcher reports on Canada's lobster fishery. The Canadian Scientist, Sept. p. 26–27.

77. HAYES, F. R. 1966. Science in the service of an industry. The work of the Fisheries Research Board of Canada. Fish. Council Canada Ann. Rept. p. 19–23.

78. TARR, H. L. A. 1967. Current problems in fish research. 1. Bacterial spoilage and its control. Fish. News Intern., **6**(8): 52, 55.

79. TARR, H. L. A. 1967. Current problems in fish research. 2. Freezing. Fish. News Intern., **6**(9): 32, 34, 36.

80. TARR, H. L. A. 1967. Current problems in fish research. 3. Nutritive value of fish. Fish. News Intern., **6**(10): 44–45.

81. WALDICHUK, MICHAEL. 1967. The detection and measurement of water pollution — chemical analysis. Canadian Fish. Rept. No. 9. p. 23–32.

82. LAUZIER, L. M., AND A. MARCOTTE. 1967. Climat marin dans les secteurs cotiers du sud-ouest du golfe Saint-Laurent. Actualités Marines, **11**(1): 15–19.

83. ELSON, P. F., AND C. J. KERSWILL. 1967. Developing criteria for pesticide residues important to fisheries. Canadian Fish. Rept. No. 9. p. 41–45.

84. SPRAGUE, J. B., AND C. P. RUGGLES. 1967. Impact of water pollution on fisheries in the Atlantic Provinces. Canadian Fish. Rept. No. 9. p. 11–15.

85. MARCH, B. E., JACOB BIELY, E. G. BLIGH, AND A. W. LANTZ. 1967. Nutrient composition of freshwater fish meals. Feedstuffs, **39**(46): 50.

86. FISHERIES RESEARCH BOARD OF CANADA (Nanaimo, B.C.). 1967. Progress in 1966 in Canadian research on problems raised by the Protocol. Intern. North Pacific Fish. Comm. Ann. Rept. 1966. p. 27–50.

87. ALDERDICE, D. F. 1967. The detection and measurement of water pollution — biological assays. Canadian Fish. Rept. No. 9. p. 33–39.

88. THOMAS, M. L. H. 1968. Anti-fouling coatings for boats. Fish. Canada, **20**(11): 18–20. [*Also*: FRB Circular No. 52, St. Andrews, N.B.]

89. JANGAARD, P. M. 1968. Suggestions for handling Atlantic coast shrimp. Fish. Canada, **20**(11): 21–22.

90. KETCHEN, K. S. 1968. Trends in marine fisheries along the Pacific coast. Fish. Canada, **20**(11): 10–16. [*Also* Trans. Am. Fish. Soc., 97(1): 82–88].

91. FORRESTER, C. R. 1968. Utilization of fish for animal food in B.C. Fish. Canada, **20**(10): 17–21.

92. TIBBO, S. N., AND L. M. LAUZIER. 1968. Abnormal water temperatures affect herring fisheries. Fish. Canada, **20**(7): 7–9.

93. GHELARDI, R. J., AND C. T. SHOOP. 1968. Will Atlantic lobsters breed in B.C. waters? Fish. Canada, **20**(9): 7–12.

94. TIBBO, S. N. 1966. The Canadian Atlantic herring fishery. Canadian Fish. Rept. No. 8. p. 7–16.

95. HODDER, V. M. 1966. Recent herring investigations in Newfoundland waters. Canadian Fish. Rept. No. 8. p. 39–54.

96. MARTIN, W. R. 1966. Herring resource research needs. Canadian Fish. Rept. No. 8. p. 63–65.

97. TARR, H. L. A. 1966. The nutritive value of herring meal. Canadian Fish. Rept. No. 8. p. 161–164.

98. IDLER, D. R. 1966. Use of herring for fish protein concentrate and low fat meal. Canadian Fish. Rept. No. 8. p. 177–191.

99. HART, J. L. 1967. Fisheries production from the northwest Atlantic. Proc. Seventh Intern. Congr. Nutr., Hamburg 1966. Vol 4: Problems of world nutrition, Symp. XV: Food from the sea. p. 1007–1014.

100. KELEHER, J. J. 1968. The keystone freshwater fishes. Zoolog, **9**(1): 6–8.

101. ACKMAN, R. G. 1968. Letter to the Editor. J. Gas Chromatog., **6**: 23A.

102. OUTRAM, D. N. 1967. 1967 herring spawning less than half average. Western Fish., November. p. 64–66.

103. KETCHEN, K. S. 1968. Trends in marine fisheries along the Pacific coast of North America. Trans. Am. Fish. Soc., **97**(1): 82–88. [Also Fish. Canada, **20**(11): 10–16.]

104. SMITH, M. S., AND T. H. BUTLER. 1968. Good shrimping areas discovered. Western Fish., March. p. 22, 24, 34, 35.

105. TAYLOR, F. H. C. 1968. What happened to the herring? Western Fish., February. p. 24, 26, 28, 30–32.

106. RICKER, W. E., AND K. H. LOFTUS. 1968. Pacific salmon move east. Fish. Council Canada Ann. Rev. p. 37–39, 43.

107. MITCHELL, E. D. 1968. North Atlantic whale research. Fish. Council Canada Ann. Rev. p. 45, 47.

108. TEMPLEMAN, W. 1967. Canadian research report, 1966. Subareas 1, 2 and 3. Intern. Comm. Northwest Atlantic Fish., Redbook, Part II. p. 3–25.

109. THOMAS, M. L. H. 1968. Control of eelgrass using 2,4-D in oyster-growing areas. Fish. Canada, **21**(3): 13–16. [Also FRB Circular No. 1, Dartmouth, N.S.]

110. MEDCOF, J. C., AND ESTHER I. LORD. 1968. Strange catch — a walrus tusk. Fish. Canada, **21**(3): 19–20.

111. FISHERIES RESEARCH BOARD OF CANADA (St. Andrews, N.B.). 1968. Anti-pollution and Atlantic salmon. Fish. Canada, **21**(1): 12–13.

112. CLAGGETT, F. G. 1968. Fish meal plant for research. Fish. Canada, **21**(1): 14–16. [Also FRB Circular No. 39, Vancouver, B.C.]

113. BLAIR, ARTHUR A. 1968. Pink salmon find new home in Newfoundland. Fish. Canada, **21**(4): 9–12.

114. THOMAS, M. L. H. 1968. Test new treatment to protect wood from marine borers. Fish. Canada, **21**(4): 17–21. Also FRB Circular No. 53, St. Andrews, N.B.]

115. BLAXLAND, MARTIN. 1968. Marine ecology laboratory studying sea's food chain. Fish. Canada, **21**(4): 22–24.

116. BRETT, J. R. 1968. The design of a new fish respirometer. Biological Problems in Water Pollution, Third Seminar, August 13–17, 1962. p. 312–314.